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AMERICAN WELDING SOCIETY

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AMERICAN WELDING SOCIETY
ESTABLISHED 1919
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Volume 6 OCTOBER, 1927 Number 10

FALL MEETING AT DETROIT

The annual fall meeting of the Society recently held in Detroit was the most successful one in the history of the organization. The total registration was about 400, which was considerably greater than that at any previous meeting. The average attendance at the sessions also exceeded previous records. The arrangement whereby our welding exposition was held in cooperation with that of the American Society for Steel Treating was very generally approved by both the exhibitors and visitors. The entertainment and inspection features were especially well planned and executed.

We are indebted to several of our members for their efforts to make these activities successful—particularly Mr. Sprau, the chairman of the Detroit Section; Mr. R. G. Richards, the chairman of the Detroit Entertainment Committee and their associates; Mr. McCune as chairman of the Exposition Committee; the Meetings and Papers Committee; our Secretary, Miss Kelly and our Technical Secretary, Mr. Spraragen. Our special thanks are also due to the American Society for Steel Treating for the many courtesies extended to our members and particularly for making us welcome to all of their entertainment features. The management of the Book-Cadillac Hotel provided excellent facilities for our meeting and it is a pleasure to record our appreciation.

F. M. FARMER,
President.

FALL MEETING

The largest and most successful fall meeting of the American Welding Society came to a close on Sept. 22. There was a registered attendance of over 400 people. The technical sessions were exceptionally well attended and the discussions spirited and very much to the point. The joint arrangement of the Exposition with the American Society for Steel Treating insured the success of this part of the program from the beginning. The fact that four technical societies held their meetings at the same time and place is an unusual occurrence. Many leaders in all branches of the metal industry were in attendance. Registration for the Society was provided at its headquarters at the Book-Cadillac Hotel.

The meeting was formally launched with the Board of Directors Meeting on Monday afternoon, Sept. 19. It was definitely decided to hold the next fall meeting in Philadelphia. Bureau activities, membership and section activities were the main topics of discussion at the Directors Meeting.

On Monday evening there was held a meeting of the American Bureau of Welding and the Joint Pressure Vessel Committee of the American Society of Mechanical Engineers and the American Bureau of Welding. A program of investigations prepared by a subcommittee under the chairmanship of Prof. H. L. Whittemore was discussed and formally approved. Plans were made for drawing up Procedure Specifications which will give complete instructions as to the welding of the test specimens and tanks needed in this investigation. Plans for financing this work also received consideration.

Five technical sessions were held and the following papers presented:

Welding the Aircraft Structure, by J. B. Johnson.

Welding in Aircraft Construction, by W. C. Naylor.

The Bend Test as Applied to Welded Coupons, by W. B. Miller.

Report of San Francisco Section's Investigations on "Study of Welds Subjected to High Temperatures."

Heat Treatment by the Oxy-Acetylene Flame, by E. E. Thum.

A Metallurgical Study of Welds, by G. R. Brophy.

The Use of Welding in Car Construction, by Victor Willoughby.

ANNUAL FALL BANQUET, AMERICAN WELDING SOCIETY, DETROIT, 1927

Automobile Welding by W. C. Happ.

Study of Oxy-Acetylene Welding as Applied to Light Gauge Pressure Containers, by H. J. Grow.

Welding in the Design of Steel Plate Work, by L. J. Sforzini.

Discussion on Structural Steel Welding, by J. E. Webster.

Arc Welding in Buildings, by Joseph Matte.

A Recent Addition to the list of Arc Welded Buildings, by G. H. Danforth.

Welding as Applied to the Reconstruction of the Havre de Grace Bridge, by J. N. Mackall.

All of these sessions were well attended and the discussions will be published in an early issue of the JOURNAL.

A special feature of the fall meeting was the large variety of entertainment provided for the ladies. The joint meeting between the four societies made this possible. No charges were made for these many events other than the registration fee of one dollar. The outstanding social success of the fall meeting program was an Annual Fall Dinner Dance of the Society held on Thursday evening. About two hundred members and guests were in attendance. A large interesting program of entertainment was provided, including receipt of the Tunney-Dempsey fight.

On Wednesday evening there was a meeting of the Structural Steel Welding Committee at which time considerable progress was made in furthering the national program of investigations to secure fundamental design data as to unit strengths needed by structural engineers. Prof. Gillespie of the University of Toronto presented a comprehensive report outlining the results of a preliminary series of tests made at the university to check up the program of tests and the procedure specifications. A number of changes were proposed which will be incorporated. Financial support for the entire investigation was assured at this meeting.

STANDARDIZATION AND RESEARCH

(Reprinted from Sept. 6, 1927, issue of Power)

Standards the use of which is mandatory must, in order to have any force in law, be established and promulgated by the constituted authority.

It is a fortunate thing for this republic that the several States relegated to the Federal Government the power "to coin money, regulate the value thereof, and of foreign coin, and fix the standard of weights and measures." The most confirmed opponent of governmental activity would not contest the necessity for the authoritative establishment of such standards and the enforcement of conformity with established values when such units are used.

The pity is that there cannot be still further centralization and reduction in the number of units in use for the same purpose.

Standardization in the use of these units is less distinctively a governmental function.

It is a matter of more than convenience to the public that articles of common use shall be uniform and interchangeable, but it has been the American policy to let the manufacturers and purveyors of such articles work out their own standards and voluntarily comply with them.

The establishment of the fundamental units is a comparatively simple matter, but it leads to research into the physical properties of materials and processes for their conversion to the use of men.

Such research is being done extensively by manufacturers' laboratories with especial reference to their own products, and they have, of course, a proprietary right in their own discoveries. But there are many such questions the solution of which is of public interest.

The Bureau of Standards, if given the necessary means, can be more than a national sealer of weights and measures. It has done and is still doing much to enlarge our knowledge of and to furnish precise values for the physical properties of the materials upon which our arts and industries and the users of their products are increasingly dependent. It should be encouraged in this broader activity. Everything that it determines or discovers is an asset to American industry and American living.

And the user pays for it and profits by it, whether it is discovered in a governmental bureau or a manufacturer's laboratory.

WELDING CONFERENCE TO BE HELD AT UNIVERSITY OF MINNESOTA IN OCTOBER

Many users of welding and cutting equipment in the Minneapolis terri-

tory are planning to attend a conference of the welding industry to be held at the University of Minnesota on October 20, 21 and 22, 1927.

Prof. S. C. Shipley, acting head of the Mechanical Engineering Department of the College of Engineering, is in charge of the program, which will be the first of its kind held in the Minnesota district.

Representative engineers will present various papers from the users' point of view and following each paper there will be a round table discussion which will make the various ideas of practical everyday value. The object of the conference is to standardize practices and to develop many new applications from the experiences of many welding experts.

Work of the American Welding Society

Article appearing in August, 1927, issue of Railway Mechanical Engineer.

Elsewhere in this issue appears the technical program of the American Welding Society to be presented at the fall meeting to be held during the week of September 19 at Detroit, Mich. In addition to the technical sessions of the American Welding Society there will be held at the same time a convention of the American Society for Steel Treating, the fall meeting of the Institute of Metals and the National Steel and Machine Tool Exposition. Each of the technical societies has prepared a splendid program.

Of particular interest to the railway industry will be the activity of the American Welding Society. Welding received its first great impetus in the railroad field, which has done much in its development and still is contributing valuable practicable information imperative to the further development of the science of welding. Many railroads have not given the American Welding Society their fullest cooperation. Perhaps the reason for this lack of cooperation is the fact that railroad shops are widely scattered, which prevents the proper dissemination of information on welding. The railroads should bear in mind that the American Welding Society is a central clearing house for accurate information on the development of the art of welding.

Perhaps many railroads are not entirely familiar with the work that the American Welding Society is doing in order more fully to develop the general science of welding. The work of the Society is carried on through a number of channels, most important of which are local sections, publications, national meetings, research department committees, and information service. Perhaps the most important of these are the activities of the research department, known as the American Bureau of Welding. It also acts as the welding research department of the National Research Council. The purpose of the Bureau is to bring to bear on the solution of welding problems the latest scientific knowledge and the scientific method of attack. To this end the cooperation of all interested in scientific and engineering organizations has been enlisted. It also provides an organization the reports of which are accepted the world over as sound and free from commercial bias. The work of the Bureau is carried on through research subcommittees, each handling specific problems. Among the problems now receiving consideration may be listed (1) welded rail joints; (2) welding pressure vessels, (3) welding of structural steel, (4) welding wire specifications, (5) fundamentals of welding and (6) fundamental problems, in welding, all of which are applicable to welding in the railway industry. As an example of the scope of the work carried on by these committees, in the field of pressure vessels the Bureau carried out a $15,000 investigation to supply engineers, and particularly the A. S. M. E. boiler code committee, with needed information which would enable it to draw up a satisfactory code governing the use of welding in the construction of pressure vessels. Recognizing the incompleteness of the present code, the A. S. M. E. has recently authorized the conduct of a joint investigation with the American Welding Society of much greater scope which will not only include particular tests but many fundamental investigations in the nature of welds and which will probably involve an expenditure of $100,000.

In addition to specific research problems the Bureau maintains a technical information service. During the past year several hundred requests for information have been satisfactorily answered. When the information is of general interest, the questions and answers are published in the Journal of the Society. Thus, it can be readily seen that through the Amerncan Welding Society reliable information and data can be secured pertaining to all branches

of welding. Are the railroads taking the fullest advantage of this fund of reliable technical information pertaining to welding? Are the railroads doing their share in cooperating with the Society pertaining to the welding problems to be solved in the railroad industry? The railroads have many men well versed in the science of welding. These men should avail themselves of the opportunities offered by the Society to take an active part in its committee work and particularly in the activities of the American Bureau of Welding.

SECTION ACTIVITIES

Northern New York Section

At a meeting of the Executive Committee of the Northern New York Section it was agreed that it is desirable to have as many meetings as possible preceded by a dinner. A meeting will be held between Oct. 15 and Oct. 30 at the Hotel Hampton, Albany, which will be preceded by an inspection trip to New York Central shops. The speaker will be Mr. E. Wanamaker. The following meetings were agreed upon, the dates of which will be announced later:

1. Inspection trip and dinner meeting at Schenectady.
2. Meeting at Schenectady; smoker and moving pictures. Talks on gas welding and demonstrations, if possible.
3. Inspection trip and dinner meeting at Pittsfield.
4. Dinner meeting at Albany—installation of officers for next year.

Philadelphia

A very successful meeting of the Philadelphia Section was held on Sept. 19 in the auditorium of the Engineers' Club. Mr. W. H. Bleecker, of the Page Steel & Wire Company, spoke on "The Manufacture of Iron and Steel Welding Wire." This paper was accompanied by moving pictures showing the complete process.

Pittsburgh

The monthly meeting of the Railway Club of Pittsburgh was held on Sept. 22 at the Fort Pitt Hotel. Mr. G. D. Fish, consulting engineer, Westinghouse Electric & Manufacturing Company, addressed the club on the subject: "Arc Welding of Structural Steel." The nomination of officers for the ensuing year took place at this meeting.

New York

The first meeting of the New York Section was held on Sept. 13. A unique feature of the New York Section meetings from now on is to be the showing of moving pictures before the main program. On the above occasion three reels of the moving picture of the National Tube Company on "The Arteries of Industry" were shown. The meeting started at 7:30 p. m. Mr. A. F. Keogh, president of the Sound Welding Company, presented an illustrated lecture on "Welding for Eternity" in connection with the welding of pipes in the Cathedral of St. John the Divine. Many of these pipes are imbedded in 6-foot concrete and, as Mr. Keogh stated, are expected to last forever. It is a satisfaction to know that these engineers decided upon welding as a permanent jointing in this work.

Mr. L. F. Hagglund, of the Under-Water Metal Cutting Corporation, presented an illustrated review on the developments of underwater cutting. Motion pictures illustrating the actual operation were shown. About 150 people were in attendance.

The next meeting of the New York Section will be held on Oct. 19. The meeting will be preceded by the remaining two reels of the "Arteries of Industry." Speakers on this occasion will be Mr. W. G. King, director, Safety Division, American Optical Company, and Mr. T. A. Walsh, safety engineer, American Optical Company.

Employment Service Bulletin

SERVICES AVAILABLE

A-64. Expert welder desires position. Have had four years' experience in welding with electric arc and gas at the Bethlehem Steel Company. Have also had teaching experience in training welders; have had two years' experience with the Bradley Pulverizer Company, welding steel castings, frames and sheet iron; and last job was five years with present company in position of welding foreman. We weld tanks, boilers and all kinds of fabrication of structural line. Can furnish references.

The Welded Joint in Aircraft Construction*

WILLIAM C. NAYLOR†

Since the advent of the acetylene torch to the aircraft industry, several radical changes have been made. In the first place, the construction has been so simplified and improved over the old wood and wire construction that this feature alone can be held responsible to a large extent for the popularity and public acceptance of the modern aircraft.

The acetylene weld was at first shunned and used in secondary structures where only minor loads occurred. Then as the engineering profession realized the advantages and shortcuts to be had with this construction it was gradually accepted and today stands as the most important means of bonding together the aircraft structure.

To fully appreciate the prominence and adaptability of welding in the aviation industry one should consider that practically every single major assembly depends at some time on the acetylene torch. In the case of some assemblies such as the fuselage, empennage, motor mount and tail skid practically the entire industry with the exception of those companies specializing in duralumin construction has standardized on welded steel tube construction. The low cost, combined with strength, lightness and rapidity of manufacture, account for the general use of this method. In some cases attempts have been made to build complete wing panels out of steel tubes welded together. Considering the strength-weight ratio this construction has been only partially successful due primarily to secondary failure in the built up spars. For this reason it is generally conceded that the wooden spars which embody more bulk and therefore offer more resistance to secondary failure, are more satisfactory.

In the case of the fuselage only a few other methods of construction present themselves. Among these are all duralumin construction, bolted fitting construction, monocoque or plywood construction, and the old wood and wired construction. The former is undoubtedly good and there is every indication that the future will see more of it but just at present it cannot compete with welded steel due to the high cost involved. The bolted fitting method is used considerably, especially in Europe, where the weld is still somewhat in mistrust. This method is also unquestionably good although very expensive on account of the multiplicity of fittings. Where this construction is used it is more economical to employ dural tubing instead of steel to utilize the saving in weight thus offered. The monocoque or plywood method also has its advantage in that it can be better stream lined. This method involves the use of forms over which the plywood is formed and secured and

*Paper presented before the annual Fall Meeting of the A. W. S., Sept. 20.

†Chief Engineer, Stinson Aircraft Corporation, Northville, Mich.

lends itself fairly well to production, but has that drawback which wood will always have, i. e., the danger of splintering in case of a crash. The old wood and wire method of construction is obsolete and deserves not even mention. However, the wire cross bracing is still used with steel tube struts and longerons and is really a very satisfactory method. In the larger ships a reasonable saving in weight can be effected by replacing the diagonal steel tube braces by double wire and turn buckle members or tie rod members. In the smaller installations it is believed that with the all-tube construction the lower cost and the security against necessity of re-rigging more than offsets the saving in weight.

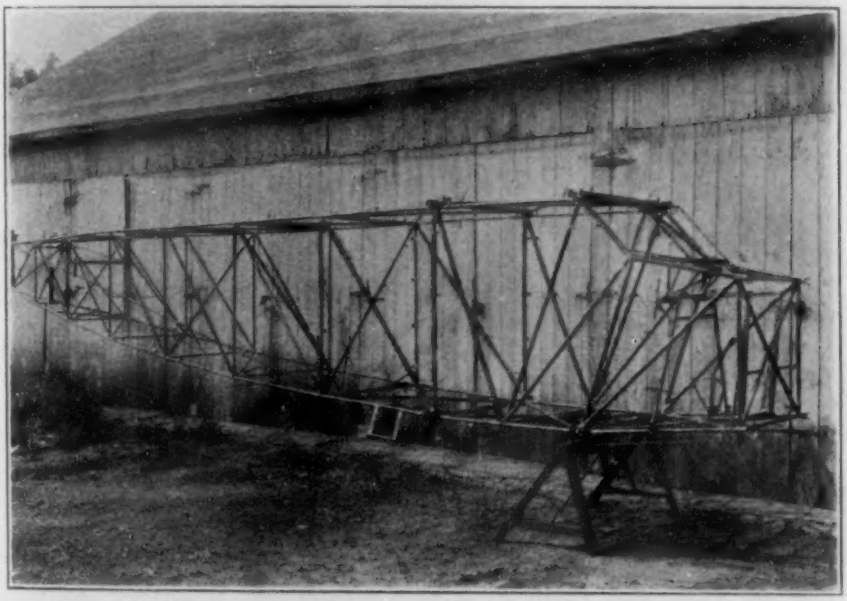


Fig. 1. Fuselage of monoplane showing wing fittings and left strut fittings, stays and some of the push-pull tube controls

A four to six place fuselage of this type can be turned out in from 50 to 75 man hours with the use of only a hack saw, a grinding wheel and an acetylene torch. It is immediately obvious why this method has been so universally used. Fig. 1 shows the fuselage of a 3300-pound airplane which is equipped with wing and lift strut fittings, stabilizer push pull tube controls and tail skid connections and represents an expenditure of 91 man hours. The total weight is 215 pounds. These figures invite comparison in that they represent a good mean average considering everything, i. e., material cost, labor cost, weight and tools necessary for manufacture.

If only an experimental fuselage is to be made up it may be constructed on a wooden jig. The welding will, of course, burn the jig and be disagreeable to the welder, but for the builder who

is only interested in one fuselage this is a very satisfactory method.

To the manufacturer, however, a steel jig is necessary. This need not be complicated. In fact, it can be very simply constructed of angle iron members bolted together on a substantial base. Where the longerons and cross tubes rest a socket and clamp is provided to insure alignment. Thus the various tubes which comprise the fuselage may be sawed to the approximate length, the ends ground to fit the corner to which they are intended and then clamped into position so the heat of the weld will not draw or

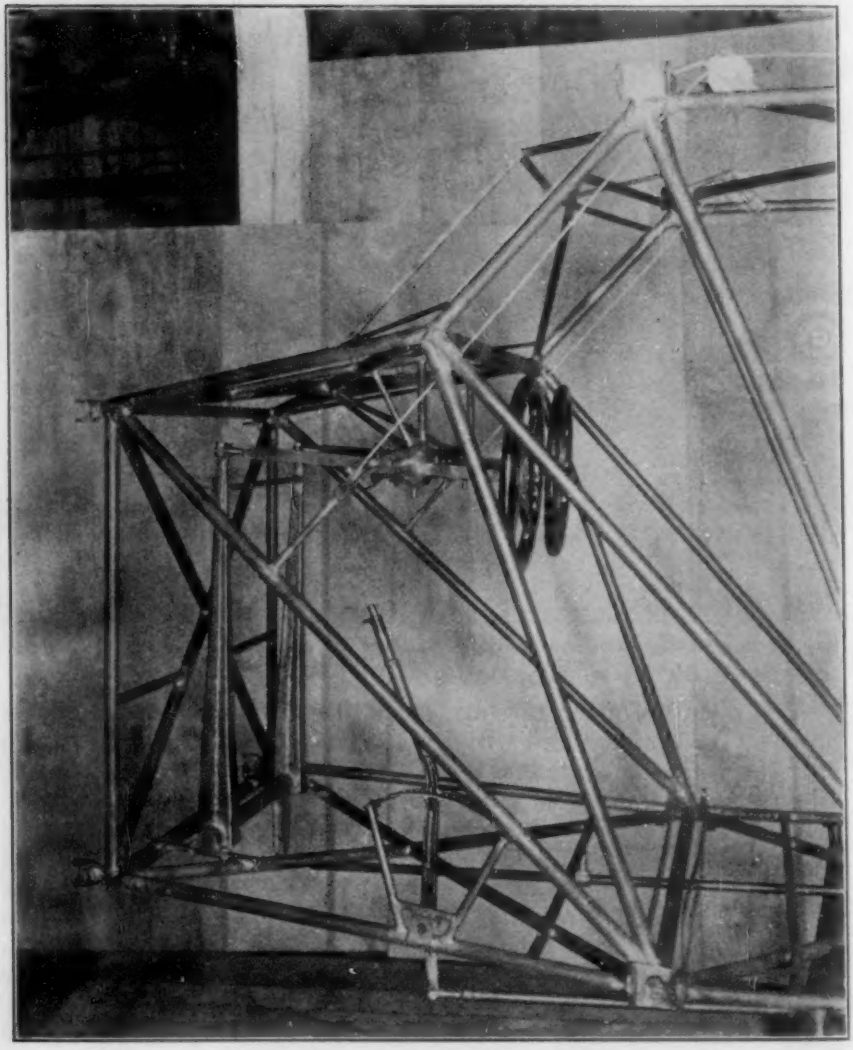


Fig. 2. View showing elevator, stabilizer and aileron control. Note the long column bell cranks used in elevator control. Elevator and stabilizer control embodies use of push-pull tubes running in graphite bearings.

shrink the structure. This is an important point in welding thin wall tubing. Of course, the heat will cause some shrinkage regardless of the jig but this may be controlled much better with substantial hold down clamps. For example, a rigid trussing with longerons forty-eight inches apart is welded up. If a second heat is applied to the cross members the distance between longerons will be found to have shrunk as much as $\frac{3}{8}$ in. If the hold down

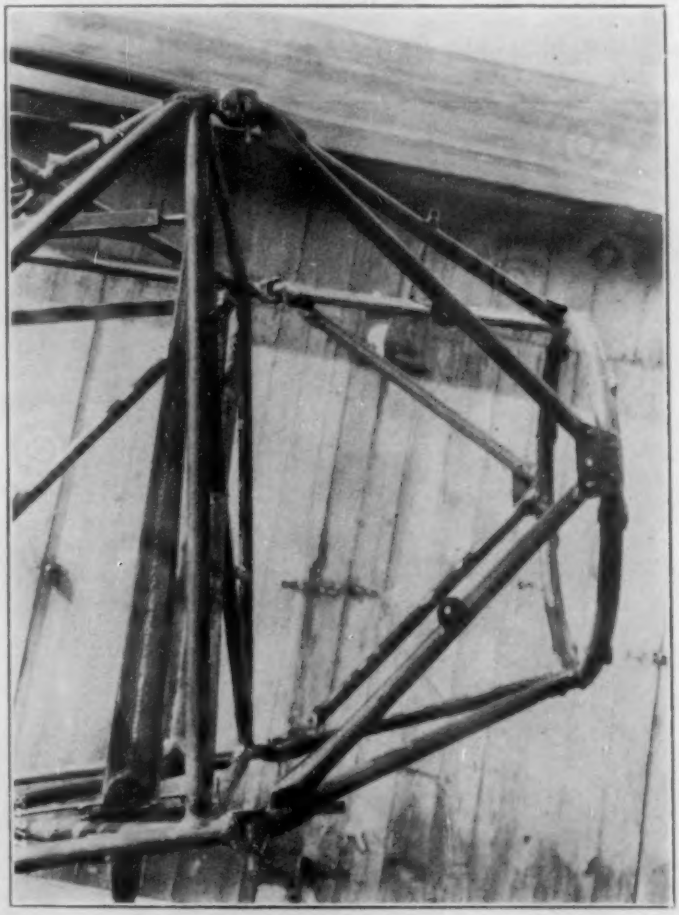


Fig. 3. Typical motor mount showing four-point suspension. Note that all welds are reinforced by gusset plates and iron rivets. Material, chrome-molybdenum tubing with carbon steel plates

clamps are located right adjacent to the welded joint, the shrinkage will be cut in one-third.

With a jig of this kind, a bench and a grinding wheel near by, it is surprising what a good welder and a helper can do in a day's time. With the helper cutting and fitting tubes and the welder working from joint to joint the work proceeds with amazing rapidity.

It is customary in aircraft construction to design a fuselage of this kind by the use of ordinary stress diagrams, knowing the external loads imposed. After the load in each tube is obtained the tube size is arrived at by the use of Euler's column formula by using a coefficient of restraint of 1. In other words, the structure is assumed pin ended at every joint. This throws some light on the reason why a welded fuselage is so seldom responsible for a failure. Regardless of this feature it is comparatively light in weight.

Ordinary carbon steel with a carbon content of from .20 to .30

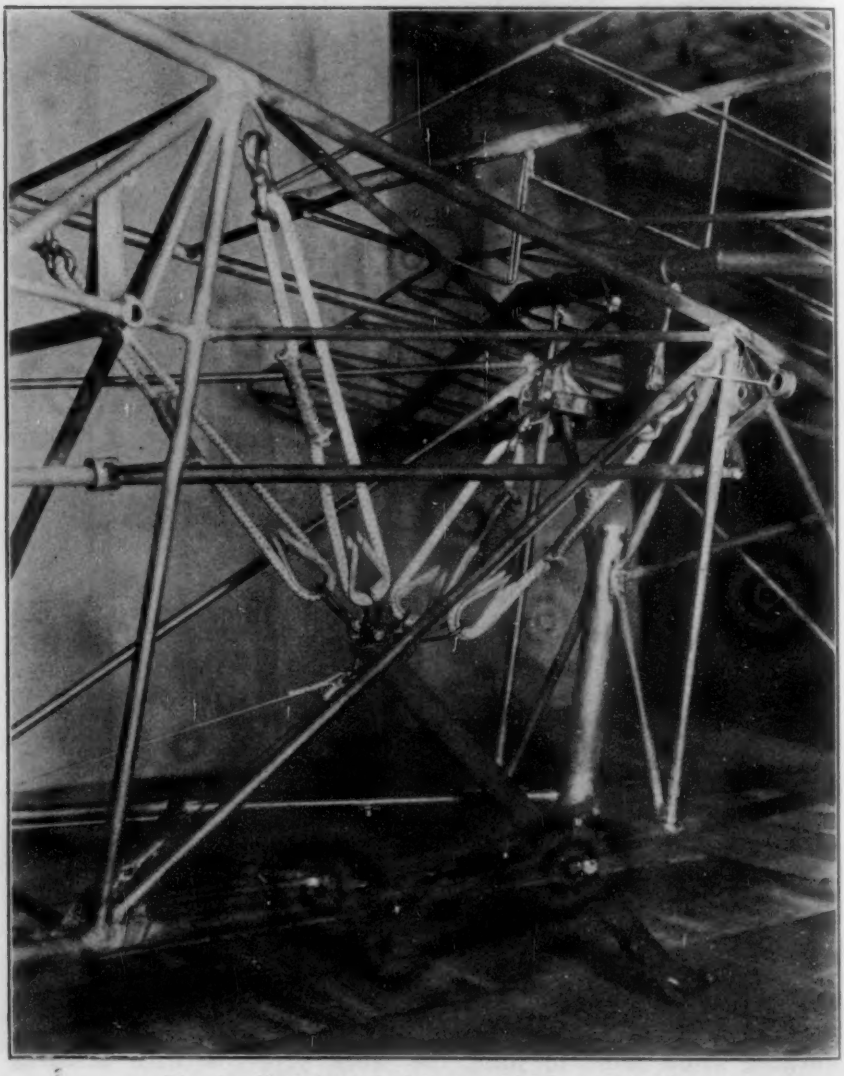


Fig. 4. Heat treated chrome-molybdenum tail skid

is generally used in commercial fuselages. A slight saving in weight can be realized by the use of chrome molybdenum but the additional cost more than offsets these. In and adjacent to the weld for a distance of approximately ½ in. the steel is reduced in carbon content by the heat, but since the function of the tube is to serve as a column, its strength is little reduced.

Landing gears have been made of various materials, but here again most constructors have settled down to welded steel construction. Chrome-molybdenum steel is almost universally used for the reason that it may be heat treated after welding to a strength more than double that of carbon steel. Thus the over-all diameter of the tubing is kept at a minimum, which reduces aero-

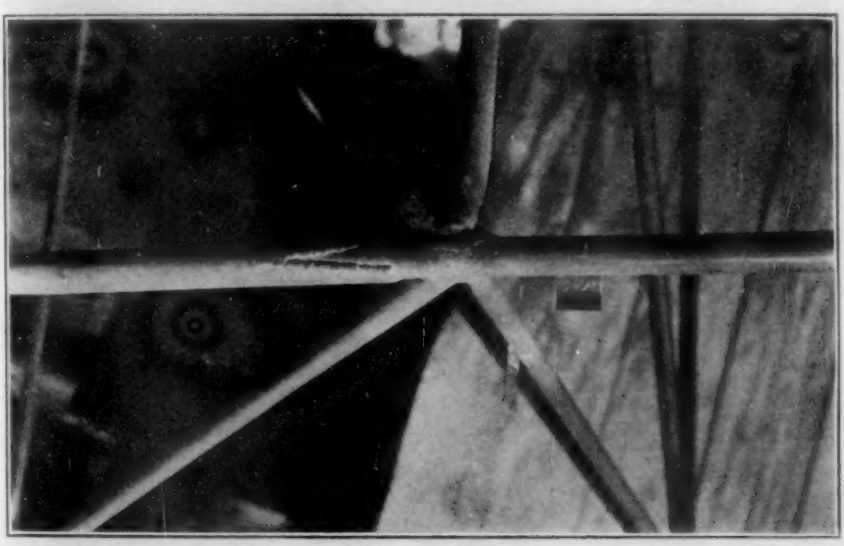


Fig. 5. Typical fish mouth weld made in longeron where tube changes size

dynamic resistance and the weight is also much reduced, especially in the axle where a large bending moment occurs. In some types of gear the front triangle exclusive of the shock absorbing unit is heat treated in one piece. This consists of a heat to 1650 deg. Fahr. quench in water and a drawing operation of from 800 deg. to 1000 deg. Fahr., depending on the strength required. The rear leg is then telescoped into a stub, already welded on, and secured by two bolts. The shock absorbing unit is then welded on at the upper end where the high loading does not occur. In this way a simple yet serviceable job is obtained.

In the case of the motor mount another problem presents itself. This is the problem of absorbing and diminishing the vibrations of the motor. When the installation is new one has only torque vibrations to contend with. After hours of service other vibrations are apt to appear in the form of unbalanced propellers, unequal

settings in pitch of propeller blades, warp in wooden blades and such mechanical adjustments as improper timing of valves, etc. Any of these disturbances aid in increasing vibration and the motor mount must be designed to bear the brunt of this. Mounts of carbon steel are satisfactory under some circumstances but the use of chrome-molybdenum is much to be preferred. The fact that this steel shows a much more homogeneous structure after welding is largely responsible. The mount shown in Fig. 3 is of conventional design and shows how the torque vibration can be best taken

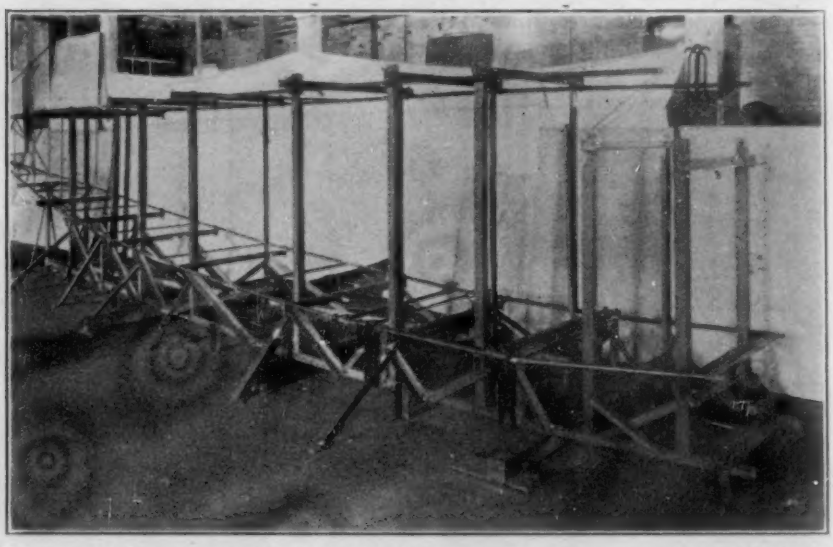


Fig. 6. Simple angle iron jig, bolted together. Small half round sockets and U bolts maintain proper alignment and dimensions. Welding of fuselage is completed before removing from jig

care of by the four sets of triangles. All welds are reinforced by gusset plates and iron rivets and the entire structure is then normalized to relieve internal stresses in the metal. A further and important precaution against failure is the use of oversize washers made of brake lining between the engine and mount. Fiber, oil soaked plywood, soft copper and imbedded cork have also been used with varying degrees of success. A welded motor mount of this design can be relied upon with safety.

The tail skid is another example of where chrome-molybdenum steel can be used to advantage. It is a well-known fact that the three assemblies which give the most trouble on an airplane are the landing gear, the tail skid and the motor mount. It is a significant fact that all three are constructed of welded chrome-molybdenum steel and heat treated. Fig. 4 shows a skid which imparts considerable live load reaction to landing and at the same time weighs but 11 lb. complete. The bending moment at the fulcrum is taken by the heat treated tube and wrap fitting reinforcement.

The empennage of an airplane presents an admirable field for welding. There are few who have failed to take advantage of this type of construction on the tail surfaces. Large tubes with thin walls constitute the spars. Other tubes are bent to form the leading and trailing edges while small tubes are welded over this frame to form ribs and maintain wing contour. The various members are then welded together in a jig. Control horns are welded direct to the spars.

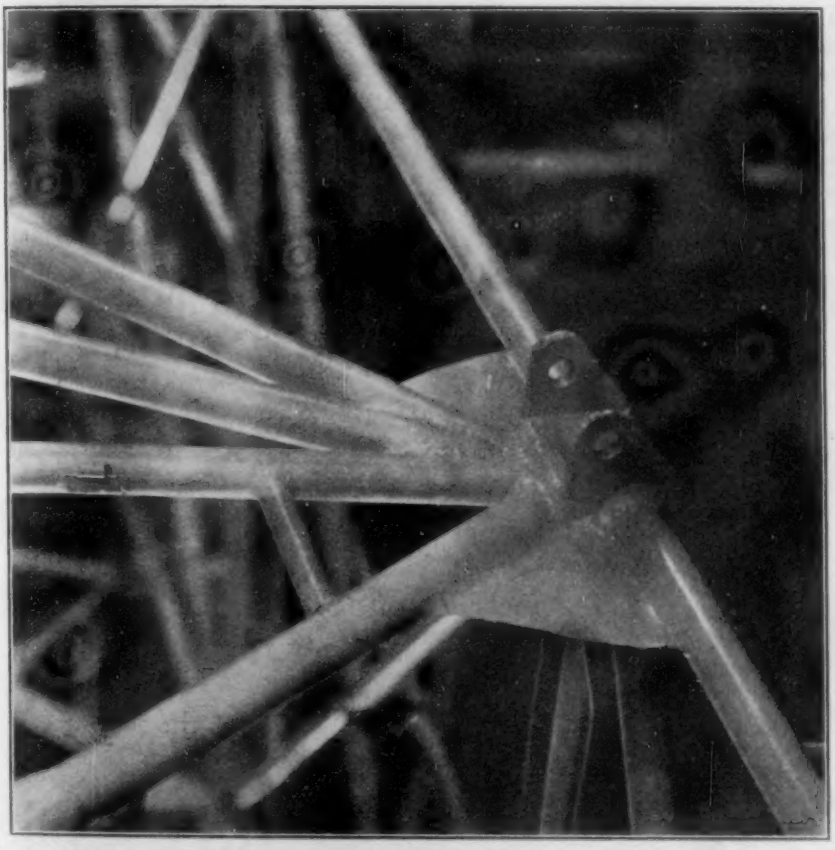


Fig. 7. Left strut fittings showing one-piece tie straps through which the longerons run

A more recent field for welding has appeared in the control system of an airplane. Push-pull tubes are gradually replacing the cable and pulley method. The tubular method insures a rigid mechanical connection at all times and although slightly heavier is thought worth while. Drop-forged clevis ends are welded into the tube end by fish tailing the tube so the weld is subjected to shear instead of tension. Screw adjustments are fitted to these controls to allow for rigging. The tubes run in special graphite bearings, which insure lubrication.

Difficulty is sometimes had in obtaining welders capable of welding light gage tubing. Since some of this material is as low as 22 gage, there is grave danger of burning the metal if the workman is not experienced. On work of this kind small tips are used, which greatly lessen this danger. Applicants are set to work welding up samples which are pulled, twisted, bent and hammered to determine whether the two metals have been really fused or simply puddle

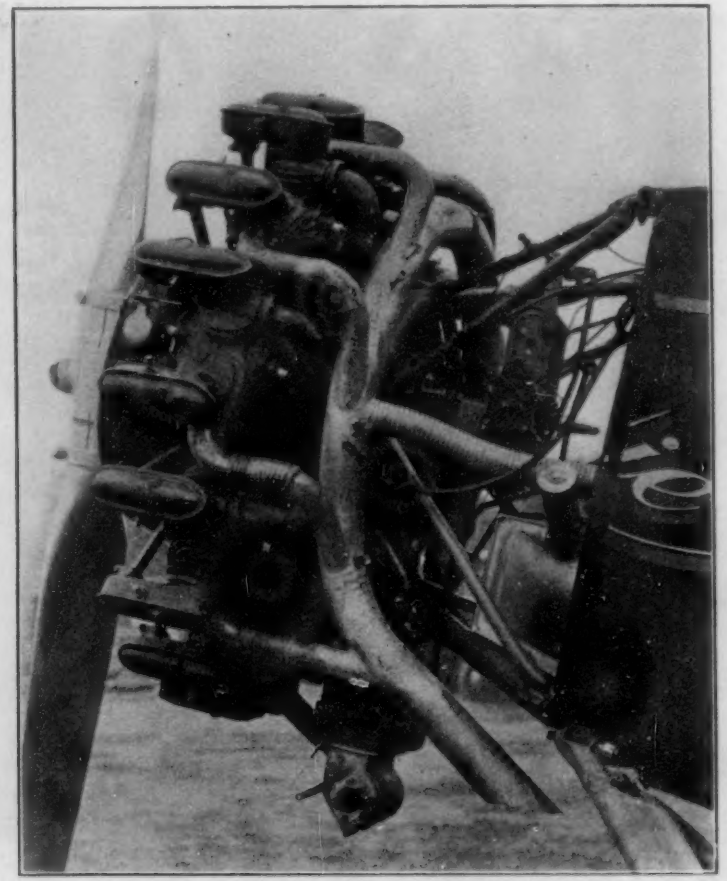


Fig. 8. Low carbon welded exhaust pipe. Note that upper two leads only are rigid

welded. A great deal of success depends on the rapidity with which the operator works, consequently a fast welder can generally be judged a good welder.

It is customary to design various assemblies so that no two members having a great difference in gage are joined by welding. This is especially true in aircraft welding where gages are necessarily low. It is a good plan to keep the maximum difference at 1/32 in. in all sizes up to $\frac{1}{8}$ in. Tip sizes from 1 to 4 are used in

this work. When the tubes are prepared for welding it is not essential that the two have contact at all points. The welder will flow the metal together provided the gap is not over 1/8 in. This accounts for the speed obtained in acetylene welding. When completed all joints should be wire brushed to remove loose scale and a good coat of metal primer applied.

The question of reliability is often brought up in connection with welding. Considering the various things that can happen to a weld and the methods of guarding against them the writer believes the question can be satisfactorily answered. Rust is the greatest enemy, while corrosion and metal fatigue rank next. Rust preventive processes are possible on small parts but impractical on fuselages, etc. Since these parts are fabric covered it is believed reasonable that a good metal primer and a coat of lacquer will protect the metal part against rust and corrosion for a period of one and one-half to two years, at which time the fabric cover should be replaced and the process repeated. With suitable vibration washers on motor mount and ordinary care used on motor and propeller, metal fatigue will cause little or no trouble in the fuselage welds. All open ended tubes should, of course, be cleaned and primed on inside as well as outside.

Field welding is a phase of the work which should receive special attention. It is often necessary to make repairs in the field where a high wind is blowing. With 20 and 22 gage tubing the welder familiar with inside welding has a tendency at first to burn the metal due to the fact that the radiation is rapid and it is only natural on the part of the operator to try to hurry the operation. When such work must be done it is well to shield the flame as much as possible.

Other uses to which the acetylene torch may be put are the manufacture of gasoline and oil tanks. By using pure aluminum a liberal saving in weight may be realized over other forms of construction such as copper, brass or terne plate. As in all aluminum welding a much lower heat is used. Even with this low heat the expansion and contraction is so pronounced that beadings or corrugations must be provided adjacent to the weld, otherwise cracks are likely to occur. The material used in tanks of 15 to 45 gal. capacity is generally 0.042 and 0.049 stock. Edges to be welded are turned up at right angles to form a 3/16 flange. Considerable experience is necessary on the part of the operator with this type of work for the reason that the temperature range is so low during the welding operation. There is no color to guide the operator as there is in the case of steel welding. As the fusion temperature is approached the torch must be handled dexteriously or the thin metal will melt, flow away and be gone before the welder realizes it. Tanks of this material may be designed to weigh as low as 0.35 and 0.40 lb. per gal.

A New Arc Welded Building*

By G. H. DANFORTH,†

In presenting an account of the new Kiln Building for The Westinghouse High Voltage Insulator Company at Derry, Pa., it is the wish to present this simply as a recent addition to the growing number of welded structural steel frame buildings that are going up in different parts of the country.

This building, of which Bernard H. Parck of Pittsburgh, Pa., is the architect, is a one-story shop building with a flat roof, part of the roof being of the high and low type of construction, in order that there will be ample light and ventilation in the interior of the building.

This building is L-shape in plan, the main body of the building being 460 ft. in length by 150 ft. in width, with one wing or L 142 ft. by 120 ft.

Roof Construction

The roof is constructed of gypsum boards laid in small tees. Reinforcing mesh is placed on the slabs after which gypsum is poured in to a depth of 3 in. and thoroughly trowled. A final top dressing of tar and gravel is applied after the poured gypsum is thoroughly set.

In the detail design, it was the desire to eliminate all close cutting of material—the usual mill variation in cutting to length of $\frac{3}{8}$ in., plus or minus, being applied to everything on the work, with the result that the bulk of the tonnage was shipped direct from the mill to the site of the building.

On account of shop conditions of the contractor, the Jones & Laughlin Steel Corporation, the detail design is a little different than would otherwise be the case, as it was not practicable at the time the work was undertaken, to do any welding at the shop. As a result of this condition, there was more punching done than would otherwise be the case.

The columns were punched and small clip angles were supplied, bolted in place for the connections of the base plates and of the seat angles under the 18-in. beam girders supporting the roof. There were also holes punched in the columns to receive a small clip angle welded to the webs of the 18-in. beam rafters, also to receive the eave struts and the spandrels coming under the windows in the raised portion of the roof.

The connections of the purlins to the beam rafters were made by a short piece of 5-in. channel welded to the top flange of the beam rafters (Fig. 3); the flanges of the channel turned upward to re-

*Paper presented before the annual Fall Meeting, A. W. S., Sept. 22.
†Contracting engineer, Jones & Laughlin Steel Corporation.

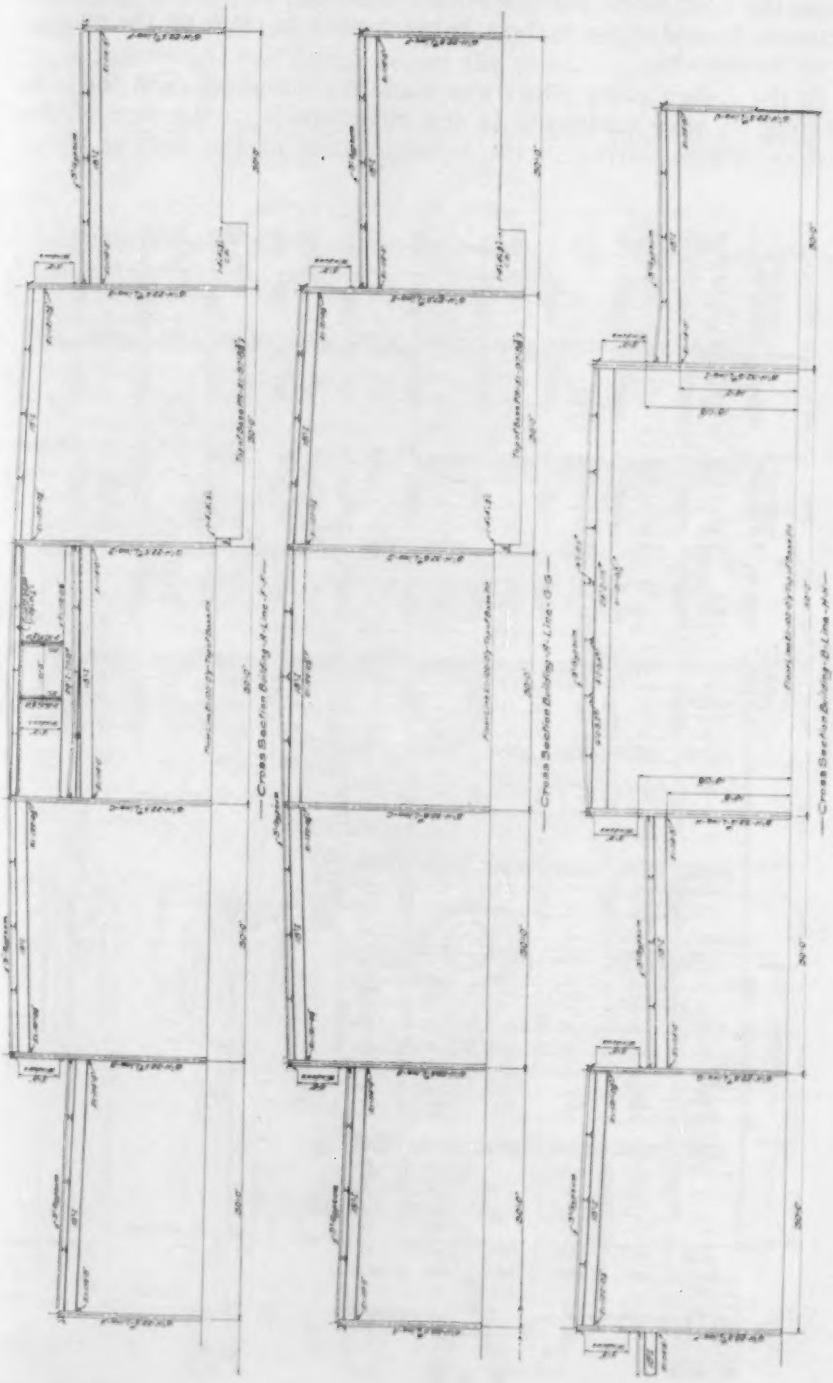


Fig. 1. Details of cross sections

ceive the 7-in. beam purlins—these channels, as well as the small clips on the end of the rafters, being welded in place on the ground prior to erection.

In the design every effort was made for simplicity and the only attempt to have continuity in the structure is in the case of the purlins, where, owing to the bottom flange of the purlins being

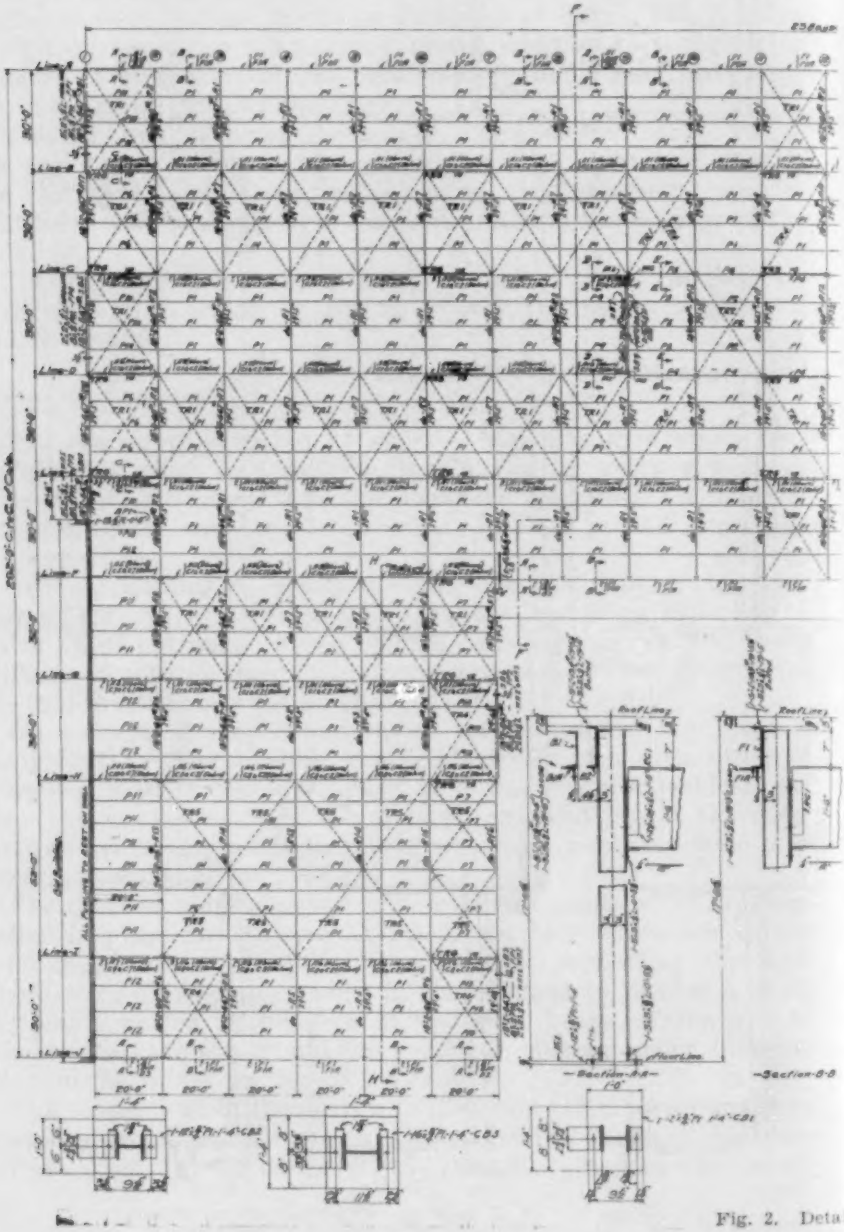
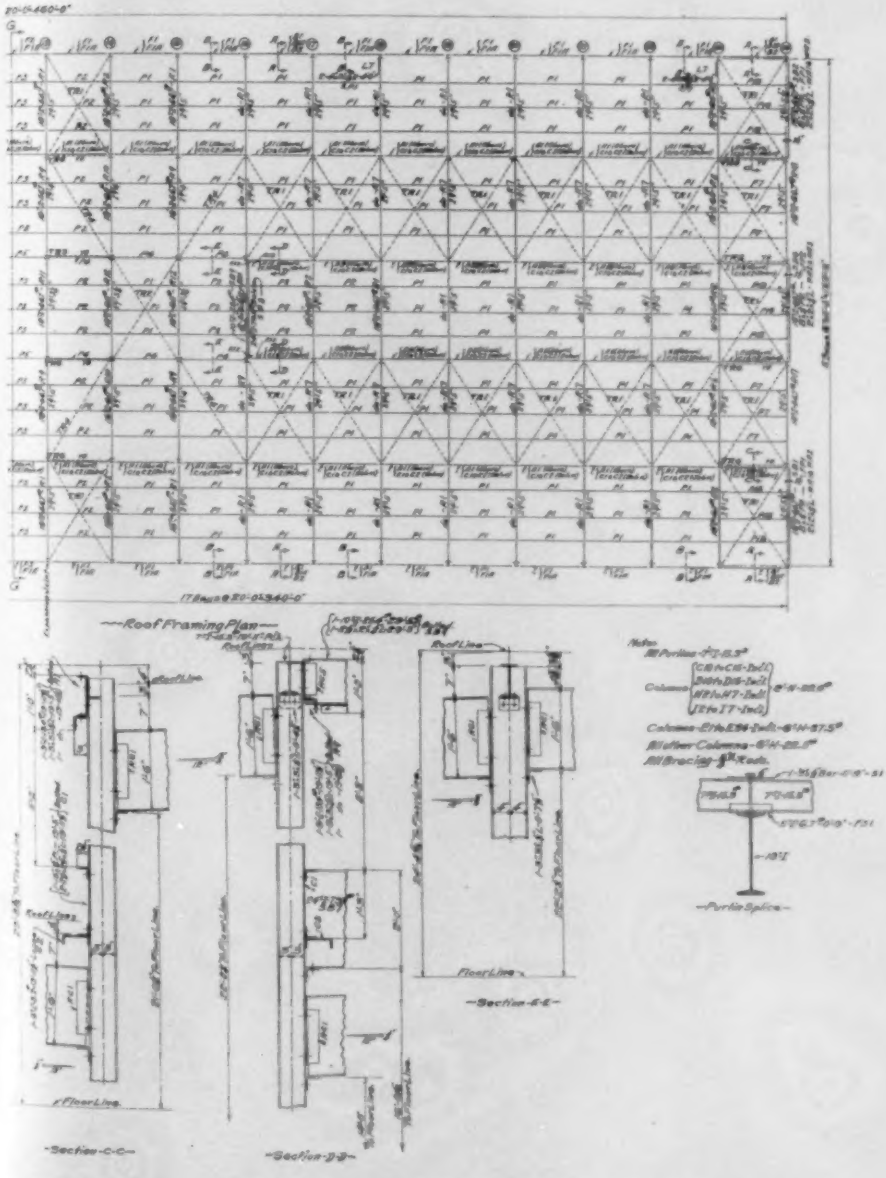


Fig. 2. Details of

welded to the small piece of 5-in. channel attached to the beam rafters, continuity could be obtained by welding a small 3-in. by ½-in. bar on the top flange across the joint.

Method of Erection

The method of handling the work permitted the entire frame to be erected in place and caught with a few bolts, the structure



Marking Plan

being perfectly stable, there being no need of doing any welding for what would ordinarily be the field connections until practically all the main body of the building was in place. By this time the ground welding (including door frames) was finished, so the three welders employed on the work were transferred to what would ordinarily be the field connections, and this work was done with such speed that they practically caught up with the erectors placing the material.

All connections that had been made by bolts for erection pur-

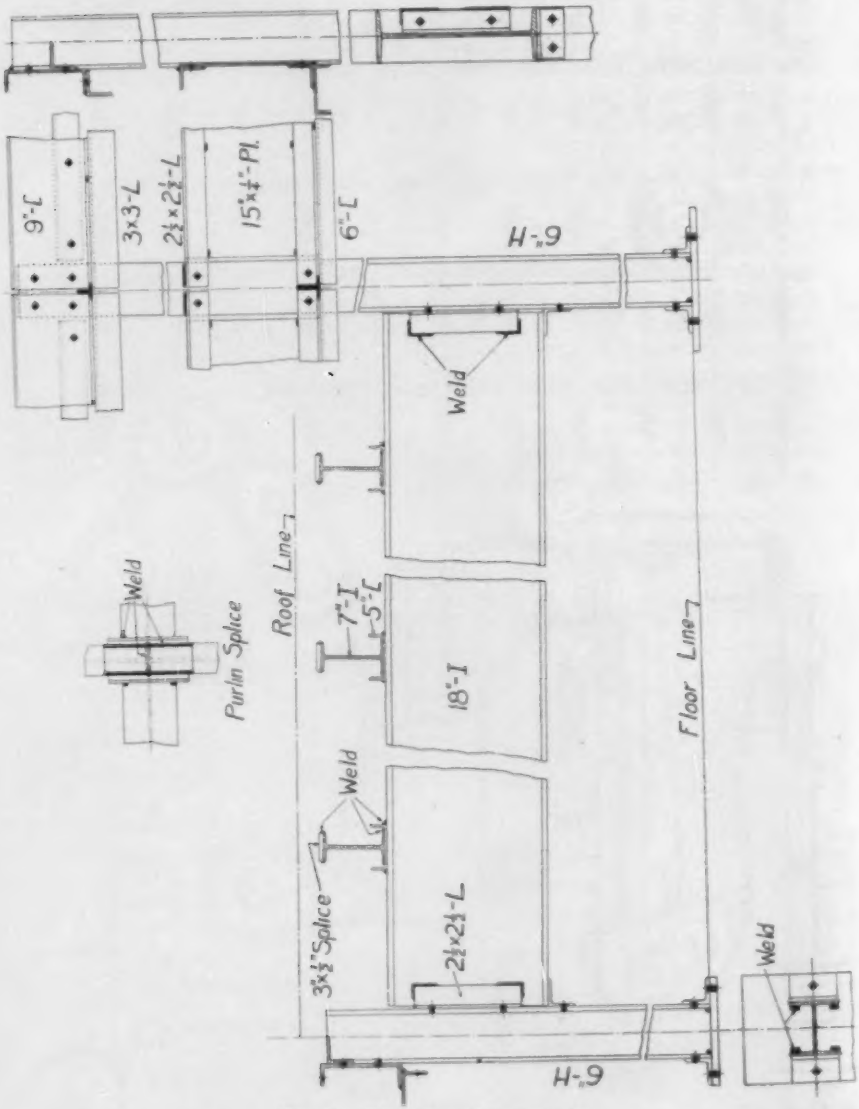


Fig. 2. Typical welding details

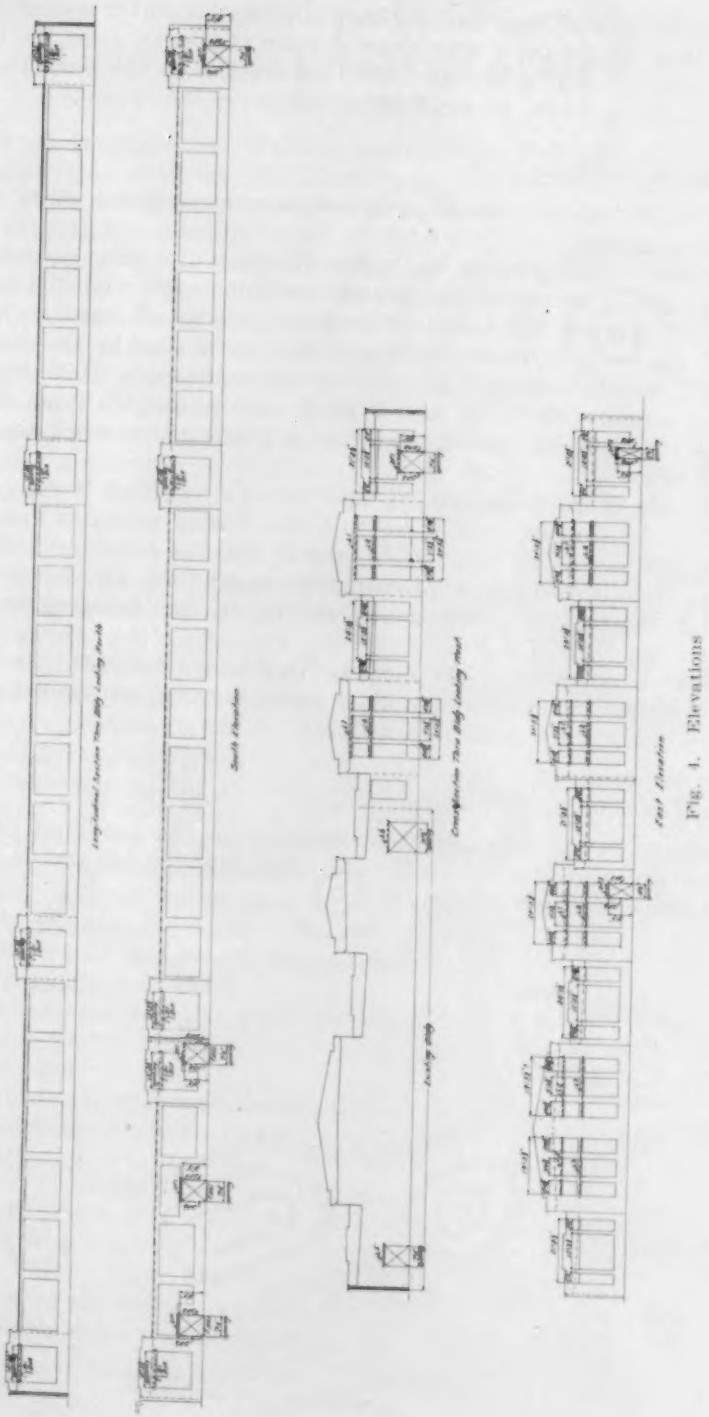


Fig. 4. Elevations

poses were welded and, as the plant now stands, there are no field connections that in any way depend upon the bolts, even the base of the column shafts having been tack-welded to the base plates. In the welding work, no scaffolding whatever was required.

Welding Equipment

Three (3) direct current single operator machines were used for the welding.

The total welding hours, including foremen and helpers, amount to 1287 hours, of which the ground welding consumed 454 hours and the field work 833 hours. This time includes all lost time waiting for material or for the placing of structural steel by the erector.

The ground welding consisted of approximately 1000 lin. ft. of fillet welds, sizes ¼ in. and 5/16 in. and in lengths from ½ in. to 4 in.; the average speed per hour in placing this work was 2.2 ft. per hour.

The field work consisted of 1100 lin. ft. of fillet welds, most 5/16 in.—in various lengths up to 5 in. There was also approximately 400 cu. in. of butt welds, and it may be considered that 1 cu. in. of butt weld is approximately equal to 1 lin. ft. of field welding, the total amounting to 1500 lin. ft., or including ground welding 2500 lin. ft.

The average speed of the field welding was 1.8 lin. ft. per hour.

This structural steel was erected under a lump sum contract and the following costs were obtained.

Welding	$7.70 per net ton
Erecting and Painting.....	15.40 per net ton

There were no difficulties encountered in the handling of this work at any time due no doubt to the fact that the job was in many ways ideal work for welding.

Study of Oxy-Acetylene Welding as Applied to Light Gauge Pressure Containers*

H. J. GROW†

At the International Welding and Cutting Exposition conducted in connection with the Fall Meeting of the American Welding Society at Buffalo last year, it was our pleasure to show as a part of our exhibit, the welding of all of the principal parts of an all-gas welded hot water heater. Many of the visitors at the Exposition stopped to see the actual welding operations, and asked various questions about the correct procedure for the different types of welds. As many of our visitors asked similar questions it was thought that a brief paper covering the more common questions might be of interest at this time. Therefore, we present herewith a limited discussion and explanation of the rudiments of welding practice applicable to products of that nature which, if correctly understood, and continuously followed, will result in the production of uniformly good welds.

Much has been written concerning good fusion and poor fusion, the weldability of the material, and quality of the welding rods as related to good and bad welds; important as these features are, their attainment alone, will not insure a high quality and serviceable weld. There are other factors not so often considered which are of equal importance, such as, suitability of the design of the weld, its location in the structure of which it is a part, and in the case of mass production the very important problem of the control and inspection of the welding and its associated operations, which properly and conscientiously carried out, insure to the management production of an article, the reliability and cost of which will meet all established standards.

To be specific, let us see how these general statements apply to one of the simpler welds made on all types of gas welded range boilers, water heaters and similar tanks—the longitudinal butt weld in the cylindrical shell.

We assume for the sake of this discussion that materials of suitable quality both for the original sheet and the welding rod, are being used.

The simple butt weld can be made in numerous ways, with varying degrees of appropriateness depending on manufacturing conditions and arrangements. For example—the open seam can be aligned correctly for welding by the use of no other special jigging equipment than a simple claw made up of say ½ in. diameter round iron which is used to spring the edges so they are parallel and in line. They are then held in this position by tacking them with a small weld every few inches as required by the nature of the work in hand. Or again, a small bolt of suitable size for the

*Paper presented at the Fall Meeting, American Welding Society, Detroit, Sept., 1927.
†Engineering Research Department, Air Reduction Sales Co., New York.

work say ½ in. to ¾ in. diameter with two washers and a nut and lock nut can be made up with sufficient space between the washers so that the edges of the sheet to be welded can be inserted. This bolt spaces the sheets so they are open in the direction in which the weld is being made and holds the edges in approximate parallelism and in alignment. The bolt can be mechanically driven along the sheet as the weld progresses thus keeping an open, well-aligned seam on which the welding operation must progress uniformly with the mechanical movement of the spacer, or the bolt may be driven along by the welder with a hammer. A third

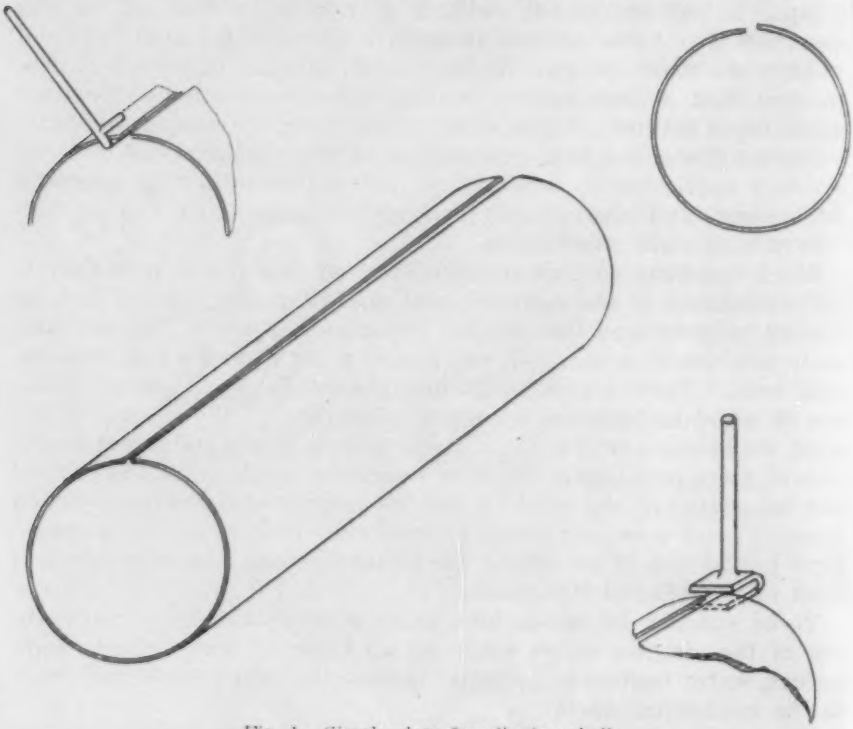


Fig. 1. Simple claw for aligning shell

method, and the one most commonly used in the larger shops where the production is sufficient to warrant its manufacture, is a special jig in the form of a solid base bar of suitable shape around which the shell is positioned. On the outside there are arranged two clamping bars that hold the two abutting edges of the sheets in position on the bottom bar. The clamps and bar are preferably made of cast iron so as to lessen the tendency to warp out of shape. A jig of this type serves several purposes and assists materially in the production of straight uniform and generally high quality welds; more will be said about this later when consideration is given to what constitutes a good weld and the precautions that are to be observed in order that good welds will always be obtained.

With these various methods to be considered, the question at once arises as to which one is best, or whether each one has its place, and if so, what factors are to be considered when deciding on how to proceed to lay out the work of a welding department to handle work of this nature. All of these processes have their advocates and are used more or less extensively in the various shops engaged in this work. We will try to point out briefly their principal faults and advantages.

But before doing this, there are one or two other things to be clearly understood, as they have a very pronounced influence on the success or failure of any welding operation. Most important among these is the preparation by correct sizing and shaping of

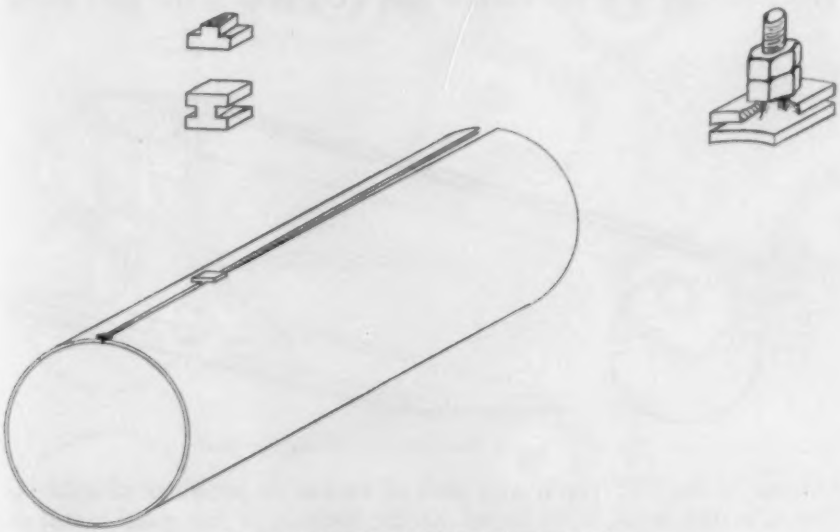


Fig. 2. Spacer method for aligning shell

the sheet. For example, if the edges are not sheared straight and true, there will be excess metal at certain places and at other places metal will be lacking, which deficiency will have to be made up at the discretion of the welder, by the addition of more filler material. This irregularity is reflected in the appearance, cost, and frequently in the quality of the finished weld. The quality is particularly affected adversely when there is so much excess material that the weld fails to penetrate through to the bottom of the joint. An item of even greater importance, is the proper and accurate forming of the sheets, so that no flat spot is formed adjacent to the edges. In other words, the curvature of the sheet due to its forming, either on bending rolls or in a press, must be such, that when the sheets are positioned for welding they form a true cylinder without any flat section at or near the joint. If flats are formed the edges draw up, as the weld contracts while being made, and the resulting distortion of the shell not only makes

it difficult to make a weld that will extend deep enough to reach all the way through the sheets, but produces a shell so distorted that a severe strain is placed on the welded joint when the shell is rounded up to permit the proper insertion of heads, or when it is rounded up by the application of the test pressure. It is also worthy of note, that the distortion due to the flat area is an accumulative distortion increasing as the weld progresses. Due to the eccentricity of the contracting weld, the deformation increases so rapidly that the weld can only be finished with great difficulty and will probably be of somewhat inferior quality.

There is also another factor to be considered when welds are made on shells having flats at the edges of the seams. It can generally be said that the poorest part of a weld is the part at the

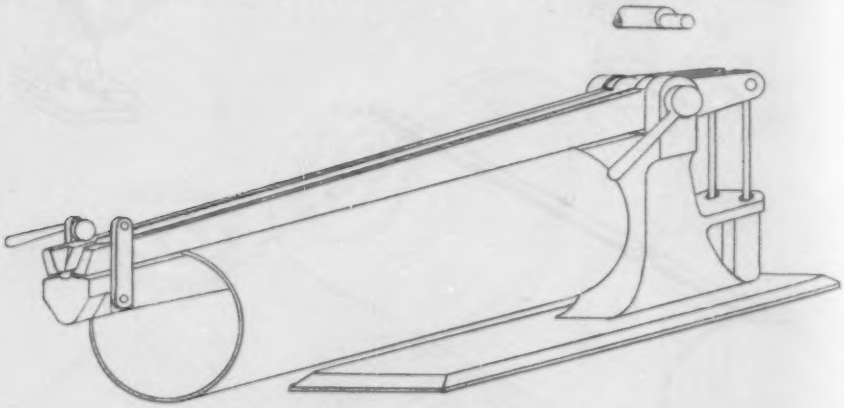


Fig. 3. Welding jig (clamp) for aligning shell

bottom of the "V" for if any lack of fusion or presence of oxide is found in the weld, it is found in the bottom of the weld metal of the original "V." Hence, with this understood, the absolute necessity of so arranging the joint that no excess strain is placed on this part of the joint is readily understood. Improper joint preparation that allows the edges to draw, aggravates this unsatisfactory condition, not only because of the poor weld metal produced and possible lack of fusion of the sheets, but when the straightening occurs, it frequently happens that the inside or bottom of the weld (as this part of the weld is distorted more than any other part of the joint) may actually crack when straightened, thus weakening the joint before it is actually put in service.

It is generally recognized that full penetration in any weld must be secured if a thoroughly satisfactory weld is to be made. Let us consider this factor also before proceeding with the more specific problems of choice of methods for setting up the work for they are in a measure interrelated with the problem of thorough penetration.

To insure the full penetration of the weld, the puddle of molten metal, must extend all the way to the bottom of the original "V,"

or to the inside corner of the edge of the thinner sheets that do not require beveling. To do this at a fair rate of speed, a tip of adequate size must be employed. Tips capable of welding at greater speed because of the capacity to burn gases in adequate quantities permit increased heat absorption, hence, the heat will travel back into the sheet away from each side of the weld a considerable distance. If a weld of this kind is attempted without special precautions, the heat line backs into the sheet as shown by the temper colors or other discoloration of the surface, it starts as a narrow line at the end of the joint where the weld begins and widens out into more or less of a rectangular figure when equilibrium condi-

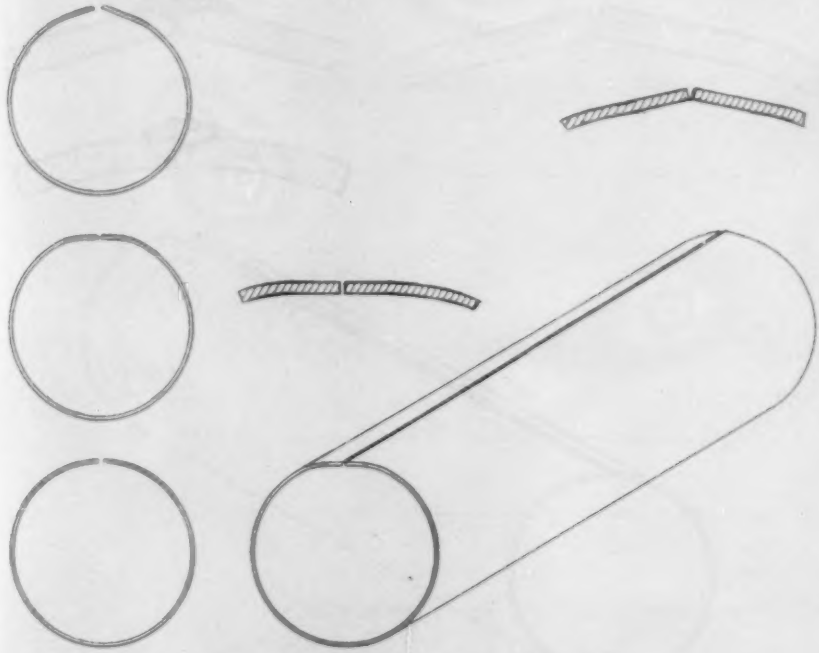


Fig. 4. Common fault—incorrect forming

tions of heating and cooling are reached. The bounderies of this heat zone, however, are far from straight, and show by their irregularity the unevenness of the heating. Uneven heating causes uneven expansion and contraction, resulting in buckles and distortion but, with proper precautions and equipment, all excess heat can be absorbed and dissipated with the result that the heat line will stop rather abruptly and show as a straight line, thus reducing distortion to a minimum.

Another of the common faults resulting from the attempt to secure high speed welding with large tips using a considerable amount of filler material on thin gauge plates, is undercutting and consequent thinning of the sheet at the edge of the weld. This undercutting sometimes occurs on one side of the weld only, and

sometimes it is found on both sides; it causes a serious weakness, as well as decidedly marring the appearance of the finished weld. Results of this kind indicate either a very decided lack of skill on the part of the welder, or gross carelessness. Undercutting can always be prevented by an even heating of the edges of the sheets with the even addition of the welding rod. Undercutting is particularly prevalent on the type of weld used to join the head to the shell in which case, it is generally due to the angle at which the torch and tip is held. Under certain conditions, the molten metal is actually moved by the application of the flame from the head at

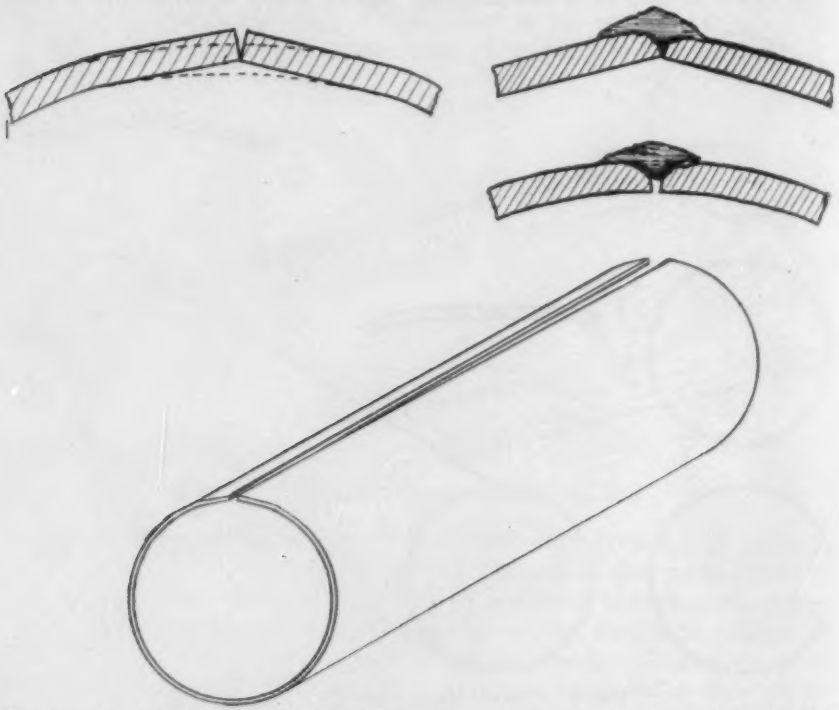


Fig. 5. Actual breaking of weld at bottom sometimes occurs during straightening of improperly formed and welded side seams

the edge of the weld to the thicker portion of the weld, thus removing it from the point where it is really needed to a point where it serves no useful purpose.

Giving due consideration to the above items, let us further consider the various schemes, or methods, previously outlined to determine their relative merits.

The first suggested method of simple tacking after the sheets are sprung into a position of suitable alignment, with subsequent welding from one end to the other of the joint, produces a good weld if proper welding procedure is employed. However, if heating distortion as described above is to be controlled and prevented,

to the extent that the joint will have the proper appearance, a small tip must be used and the operator must give strict attention to the work. Most welders of today, on account of the conditions usually found in shops, will not give the attention and concentration to this sort of work that is necessary if high quality work is to be attained. Also, in this sort of joint, where there is no chance for a general movement of the sheets to relieve the strains of welding, more strain is set up in the joint and adjacent to it, then in joints where the sheet can move readily. (From the shop's standpoint, however, there is a very real advantage offsetting these

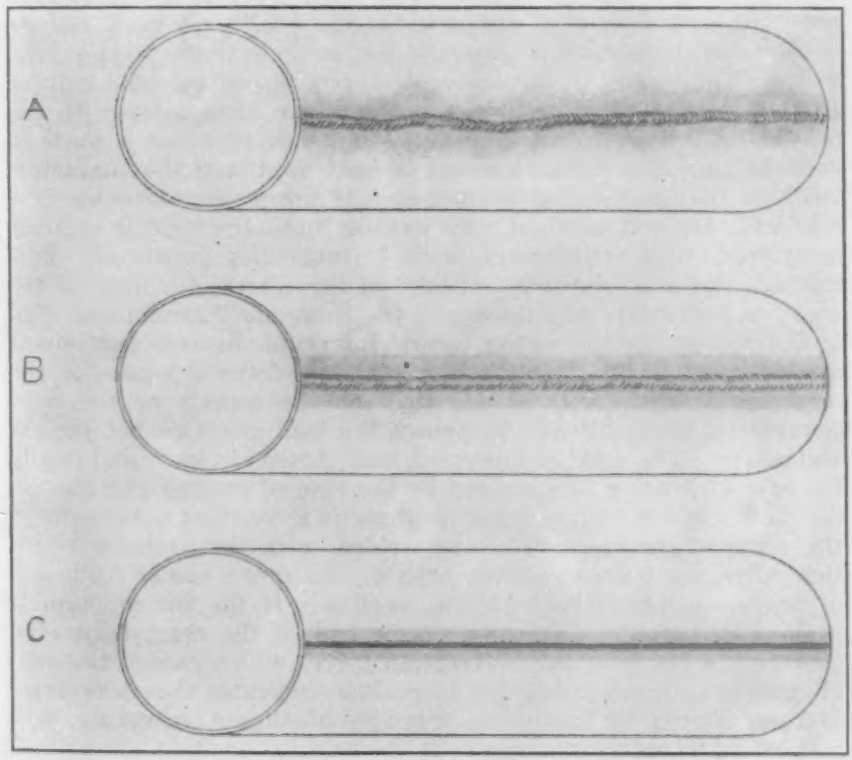


Fig. 6. A—Heat zones—irregular welding
B—Heat zones—uniform welding
C—Heat zones—uniform welding with chills

criticisms, for with this type of procedure the steady progress of the actual making of the weld, that must be observed in other methods, can be ignored.) No relative movement of the sheets will occur during the interruption, which would interfere with the continuation of the weld afterwards, if the joint is properly tacked. The strains set up is a matter not readily determined, although it can be easily shown that they sometimes reach a fairly high percentage. Regardless, however, of these strains, a good gas weld will not fail to stand up and perform its full function under these

conditions. To sum up, with this type of procedure, no special equipment is required, small tips are used, the welding technique is easily learned, for the operations are not speeded up and the welds are usually of good appearance and quality. Offsetting these good points, are the facts, that the welding rate is low, the welder's concentrated attention is required, and the finished weld may be under more strain than is the case under other welding conditions.

The second method described is also simple, insofar as the equipment required is only a bolt of suitable size with washers and nuts or other simple spacing devices. The actual operation, however, is not quite as simple as it appears, for the quality of work and its expeditious completion is generally left entirely to the welder, who welds at any rate he chooses and otherwise controls the results. In this method of procedure, the sheets are always set with the conventional wedge shaped opening, the angle of which is made to suit the rate of welding, amount of heat used, and the characteristics of the sheet being worked on. If the welder operates at a uniform rate and does not stop welding until the weld is entirely completed, very satisfactory work is invariably produced. This method, however, depends entirely on the correct forming of the sheet as previously explained and the thorough training and skill of the welder, for the welder cannot interrupt the even continuous advancement of the weld to correct badly formed joints, or the crawling of the sheets should they not lie quietly as the weld progresses, because when he pauses the heat zones do not remain stationary. The zone of increased heat moves outward and finally the rate of heating is equalized by the rate of cooling and the job cools off. While this is going on there is a constant movement of the edges of the sheet yet to be welded, with the probable result that when the welder resumes activity the sheets are so badly out of line as to interfere with the welding. If the interruption is prolonged, the edges at the extreme end of the seam may even overlap. A study of the contraction forces which caused the misalignment or overlapping due to cooling, indicates that a reversal of these forces by expansion through intelligent reheating, will restore the edges to approximately the original position when welding ceased and welding can then be resumed. Various modifications of the method of welding just described are used in some instances to the extent of moving the wedge or clamp mechanism uniformly along the joint ahead of the weld, by power, and thus try to establish the rate of welding and cause the entire seam to be completed without interruption. These devices, however, good as they may be for the purpose of securing certain features, introduce more complications than need be, as will be seen when the next method is described.

The third method mentioned, the use of a specially designed clamp, is perhaps the best of the three and more generally used. We will try to describe herewith the fundamental reasons why

these clamps assist, as we believe shops frequently use this method because it is the generally accepted one. If the functions and their influences were better understood minor difficulties in the use of these clamps would be more readily corrected and their full value be obtained.

Realizing the fundamental nature of these factors of good welding, let us repeat the very important reactions to be considered and to which proper attention should be given if a good appearance and strong longitudinal butt welds are to be produced. It is of the greatest importance that the weld is carried entirely through the full thickness of the sheet. The welded portion must be practically symmetrical with respect to the center line of the shell, and it must be steadily and uniformly made from one end to the other. One need hardly mention that the metal of the weld must be of high quality and free from porosity or laminations; this desirable condition is bound to follow the use of suitable material and ap-

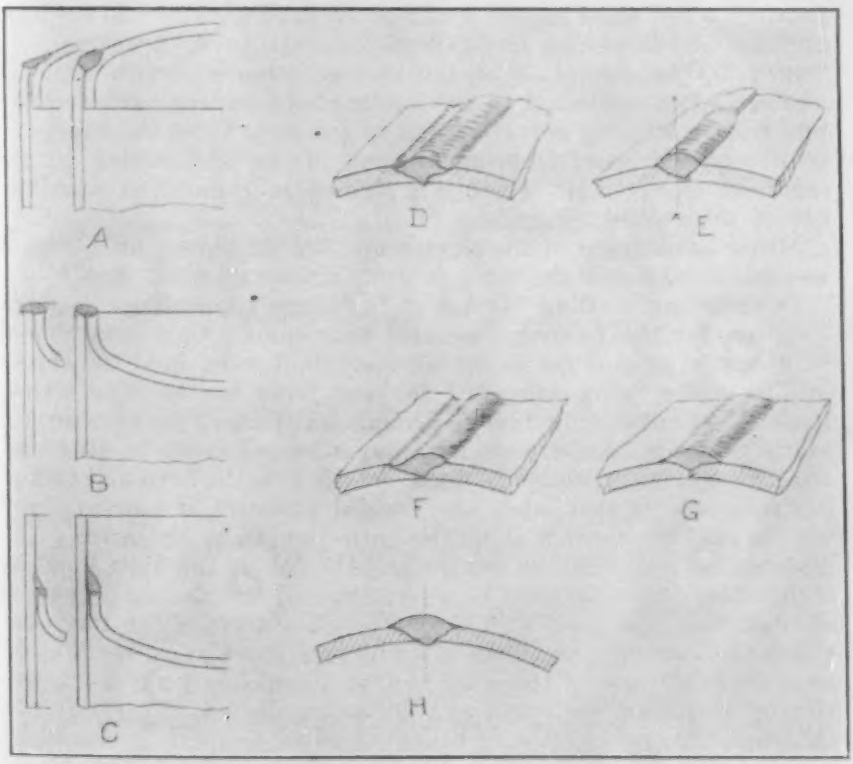


Fig. 7. A—Correct (right) and incorrect (left) weld joining top and shell
B—Correct (right) and incorrect (left) edge weld joining bottom and shell
C—Correct (right) and incorrect (left) fillet weld joining bottom and shell
D—Incorrect butt weld, thin at edges through overheating
E—Incorrect butt weld with insufficient penetration due largely to eccentricity of weld
F—Incorrect butt weld, thrown on one side through uneven application of heat
G—Incorrect butt weld through lack of penetration
H—Correct appearance of butt weld

paratus when the welding technique follows generally recognized and approved procedure.

Let us see how these factors are affected by the use of suitably designed clamps as mentioned as the third method.

One of the important advantages of the clamps providing they are of sufficiently heavy construction, is that the sheets are shaped and brought into absolute alignment. The clamps also restrain the sheets so that the sheets creep in at a uniform rate through the clamps to close the wedge shape opening always left between the edges of the sheet when the weld is started. This movement allows the normal motion of the edges and greatly helps to keep the shell properly and correctly positioned and satisfactorily shaped when the weld is finished. The clamps also act as chills carrying off excess heat and allowing the use of more heat through the use of a larger tip and flame than would be possible without the use of clamps; this in turn means a greater footage of welding per day. With the uniform cooling the welder will find it less difficult to carry a full sized puddle, heating and cooling rates will be more uniform and therefore, more simple to control. As previously referred to, the clamps allow the sheets to move in their normal manner when subjected to the heating and cooling cycles of the progressive welding operation, but at the same time, the edges are positively restrained from moving out of line and setting up the condition of eccentric welding explained in connection with the use of the second method.

Minor advantages of the clamps are, the simple set up afforded, and guide furnished the torch in some classes of work.

In designing welding fixtures of the clamp type, allowance must be made for the following general provisions. Cast iron should be used throughout for those members that must hold the sheets in line while being subjected to heat from the welding flame. Rolled steel members generally are not satisfactory for this service as they change shape more rapidly under repeated heating and cooling. Sufficient backbone must be built into the horn and clamping members so that when the desired pressure is exerted there will be uniform contact along the entire length of the seam. The distance between the top clamps and the top of the horn immediately under the weld must be altered to suit the various thickness of material. Provision should also be made to vary the space between the clamping members so as to present an adequate area of steel on either side of the seam so that a sufficiently rapid absorption of heat may occur and welding accomplished with speed and thoroughness. If maximum benefit is to be secured, it should be noted that with a wider space less heat will be lost into the clamps but the operation requires more care on account of less rigidity of the unsupported edges, less accurate positioning and less rapid chilling; a space that is too narrow increases the difficulty of making a weld completely through the sheet to such a point that it may be impossible to secure complete penetration without using a tip

H—Correct appearance of butt weld

so large that the weld is apt to be overheated. When only a little space is provided, in a jig of this kind, the welding apparatus is apt to suffer severe abuse due to the confined heat from the secondary flame.

To sum up for this method, a properly designed clamping device simplifies the welding of the most important joint by correcting slight irregularities in the forming; by providing a guiding action assisting in the seam alignment and by restraining or controlling the draw of the sheet as the weld is being made. Welders are easily taught when seams are accurately positioned and uniformly good welds can be made, higher welding speed can be secured

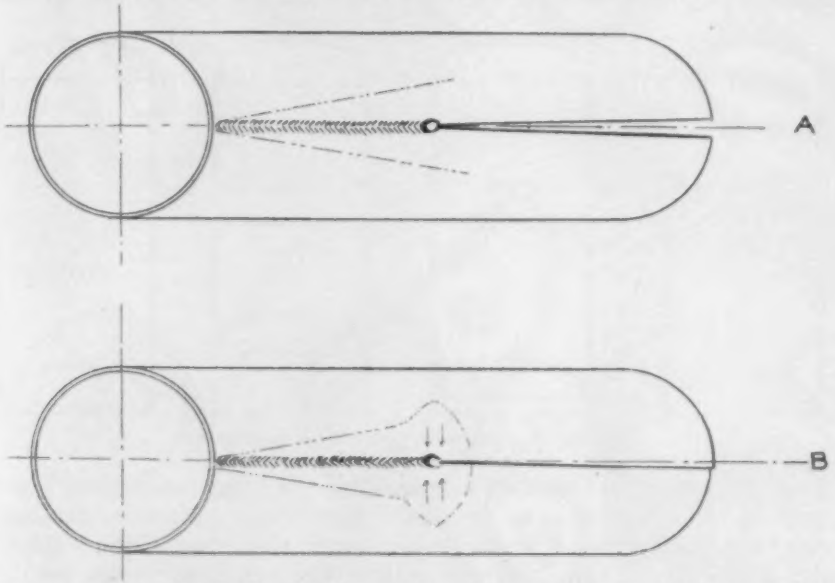


Fig. 8. A—Heat zone uniform welding with uniform expansion and closing of edges
B—Heat zone with effect when weld is interrupted

through the simplified heat control and ease of carrying a full-sized puddle and straight seams of good appearance can easily be obtained.

In the welding of cylindrical pressure tanks of all sorts probably the weld next important to the longitudinal weld in the shell from the standpoint of the extent of the complications that require consideration in the choice of a method and procedure to be followed as an accepted standard for the individual shop, are the welds joining the head and bottom to the cylindrical shell. There are in general two types of heads, convex and concave and three styles of joints, a butt weld, a lap weld and an edge weld. The butt weld is used when the pressures are high and for other specific reasons that need not be mentioned in this paper as we are restricting ourselves only to the welding considerations. The lap joint is found where a formed head is provided with a cylindrical shaped

flange that closely fits the shell. The edge weld is formed when the same shaped head as referred to above is inserted into the shell so it is concave on the outside and the end of its flange is approximately flush with the end of the shell.

Various problems are presented with the different designs. In the case of the butt joint the shell and head flange must first of all be exactly of the same size and contour or they cannot be properly fitted up. Next, the edge of the shell acts as a rigid member when the weld is being made, and starting at one point and welding continuously around the shell until the starting point is reached, some expansion difficulty will be experienced. There is a simple remedy for this trouble, through the accurate positioning of the

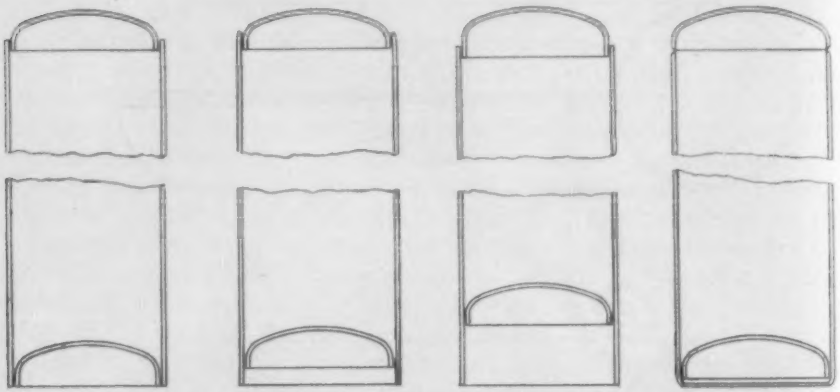


Fig. 9. Types of head and bottom assemblies

head in respect to the shell and tacking the head securely in position on the quarters or in smaller subdivisions. Each subdivision can be welded without undue distortion or straining of the weld as the flexibility of the head will relieve the principal stress set up by the contraction of the weld.

The lapped type of joint is the most common for it permits a very satisfactory and simple type of set up, and gives satisfactory service. Sometimes in joints of this type the head is inserted only far enough into shell so that the weld is a simple lap weld on the straight portion of the flange of the head. While this gives certain advantages, through saving weight and making a simple set up operation, a very much stronger type of joint can be secured if the head is inserted further into the shell and the end of the shell crimped down over the knuckle of the head so that part of the load on the head, when the tank is under pressure, will be carried by the shell irrespective of the amount transferred through the weld. The principal difficulty experienced in making either of these types of welds is that of securing close contact between head and shall before the weld is made and during its actual progress. If a space is left, good welding is made more difficult. As the weld progresses the outside sheet expands so that it becomes increasingly larger

found where a formed head is provided with a cylindrical shaped

than the inside member thus aggravating the condition. The heads are usually welded with the shells in a vertical position and the weld is therefore horizontal and easily made. As will be explained later in this paper much of the quality of this weld depends on the provision made for the comfort of the welder and the facilities offered in the way of turning the tanks, keeping the various lengths and therefore, heights of the tanks at suitable and convenient welding positions.

In the welding of the conventional bottom which is inserted so that it is concave on the outside, it is possible to so arrange the weld that an edge weld can be made. On the other hand, the bot-

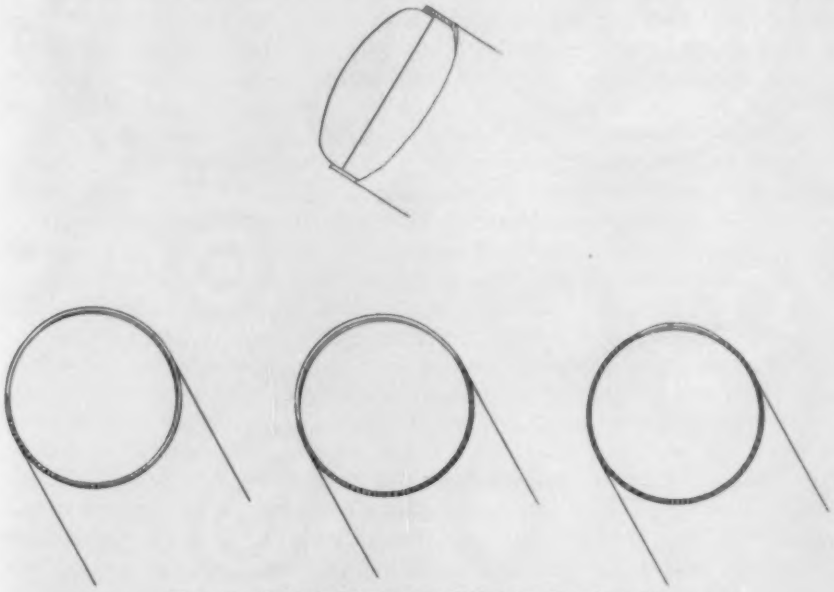


Fig. 10. Effect of improper fitting head and shell

tom may be inserted further into the cylindrical shell with the result that a lap weld must be made in a confined space frequently some distance from the outside edge of shell. When attempting to make the latter type of weld the position of the tank with respect to the welder is important. To explain this let us point out that the tank must in the first place be in a position (if the weld is made some distance from the outside edge) so that the reflected heat can be directed away from the welder in such a manner as not to interfere with his comfort or his ability to see the weld he is making. Consideration of this feature will also lead to less abuse of the apparatus than if the full reflected heat is allowed to go back around the torch.

It will be found preferable from quality and cost considerations, to make the weld a short distance from the bottom center of the circle rotating the tank periodically and frequently as the weld

progresses. Where the welder is working on a piecework rate, in which time is the only factor considered, he will soon find out that a faster weld can be made if he carries his weld so that it advances in a downward direction. The reason for this increased speed is because in this position the hot metal in the puddle because of its fluid condition tends to drop downward over the parent metal very readily and because of this tendency, the welding rod is usually

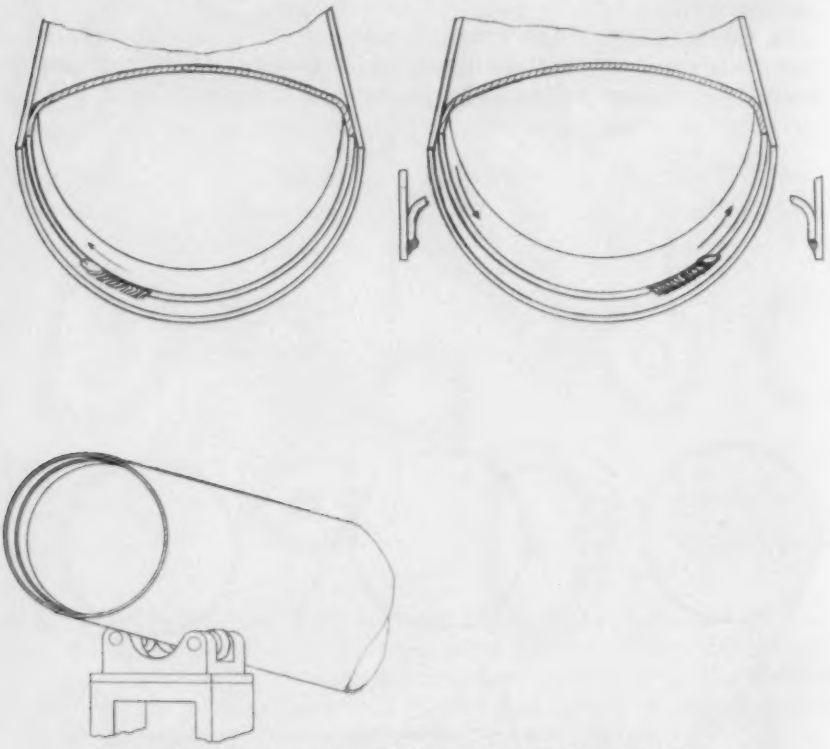


Fig. 11. Correct and incorrect direction of welding of bottoms

fed into the weld faster than the surface of the parent material is heated to fusion.

When the welder carries his weld downward in this manner, it will generally be observed that the weld is thin and sometimes hollow, also it is more prone to leak because of cold shuts due to improper fusion with the parent metal. It is generally conceded that welds made in this direction, unless the welder is particularly competent, are inadvisable. On the other hand, welds made upward in a vertical direction on account of the natural repose of the fluid weld metal, will fill out to reasonable thickness and will be found well fused to the parent material. While it is true that many welders can only make a weld where the welding is done in a flat or horizontal position, it is not difficult to teach them to weld upward in a vertical direction. If this is done on this type of

work, good welds will be made and less rigid inspection will be found necessary.

An edge weld joining the bottom to the shell is not satisfactory when high test pressures must be carried, for in this type of weld the weakest point of the weld is found at the point of greatest stress. Also, it is obvious that reinforcing on a weld of this kind cannot increase its strength beyond a certain value for the strength of the joint is determined at a point through the sheet at the bottom of the weld. There is also to be considered in connection with the statement concerning the strength of an edge weld, the fact that a poor weld may readily result through carelessness in work of this type, because practically all of the heat that is absorbed and carried back into the sheet must be picked up largely through the edge, rather than through the surface of the sheet, where a greater area for a given volume of metal would be exposed to the heating action of the flame.

In the general classification of welds on light gauge tanks there is one that offers an interesting problem, namely, the joining of the heavier sections to the lighter sections made necessary because of the common method employed for making connections to the tanks. Pipe connections are generally made by means of drop forged spuds of particular design which are welded by means of a fillet weld to the heads, bottoms or shells, as required for the particular use and design of the tank. It is common practice in most shops to have the beginners and less-experienced welders weld the spuds into the heads before the heads are welded to the shell and to weld the spuds to the shell after the tank is practically completed in other respects. It is very common practice, because of the likelihood of overheating the thin section or underheating the heavy section, to preheat the spuds which are of the heavier section, in a small oil-fired muffle furnace and apply the spuds which are red hot, to the shell and immediately weld them. When doing the welding this way it becomes a very simple operation, as the rate of heating of the two different sections is equalized. Good penetration is easily secured together with a very nicely finished appearance of the weld. Considerable time and gases are saved, all of which in the long run, more than pays for the additional effort, and cost of the preheating.

In the case of the conventional short spud little or no trouble is experienced in making the weld so that the threads will properly line up at right angles or any other predetermined angle to the surface to which they are attached. However, when the longer fittings are used particularly in the case of larger diameters and heavier material, care must be exercised when setting the job up for welding so that when the final contraction of the weld has taken place, the spud will be in correct alignment. The common method of accomplishing this is to purposely set the spud up out of the line it must occupy when finished, in such a manner that the

contraction of the weld will draw the spud so that it will be in correct alignment when cold.

This may sound like a complicated procedure, but it really is not, for with a very small amount of experimenting concerning the correct place to start and stop the weld and the amount of misalignment to allow in the original set up, will establish a procedure which if followed, will insure all the spuds being in approximately correct alignment when the job is completed.

As we have previously referred to some of the special problems arising by virtue of the fact that mass production is often attempted in the manufacture of light gauge tanks, let us consider a few more of the particular problems of mass production.

Where the subject of large scale welding is considered, one hears discussions concerning the availability of competent welders and the best ways and means of training less skillful welders to supply the needs of the large scale operations. It has always been our experience that a sufficient number of competent welders can be secured to form the nucleus of the welding gang and with the choice of the remainder of the necessary crew placed in the hands of one who could take partially trained welders and educate them as to what is expected of them on the particular job at hand, no trouble would be experienced in recruiting the welding force. Just a word, however, about the duties of those to whom the task of organizing that force is entrusted. Much can be learned about an applicant for a job on the welding force from an interview, but nothing can take the place of a quietly conducted test, in which the applicant actually welds sample work or test pieces similar to the work he is to do in actual production. The applicant should be watched so that his general conduct and apparent familiarity with what he is doing can be observed, but he should not be embarrassed or made self-conscious. The welds he makes should be tested to destruction in his presence, and his faults, if any, shown so that he can remedy them. If a welder comes through an examination of this sort and shows himself competent he can generally be put to work with a little instruction about any of the peculiarities of the job in question or particular methods to be followed. On the other hand, a little judicious instruction and assistance given the applicant, who for some easily-corrected fault, fails to do work of an acceptable standard, will frequently with surprisingly little training and effort correct the faults sufficiently to allow him to go on with the regular production jobs. It is a mistake to merely take anyone applying through the employment office, for a job as a welder and turn him over to the welding foreman to be put to work or tried out on the regular production work, aside from the fact that many applicants will overrate their welding ability, for in every good shop certain standards have been adopted and are followed as to the method of doing the work and the classification of what is an acceptable weld and what is not acceptable. These standards vary widely in different shops and if the prospect is not

familiar with the particular ones in vogue in the shop where he is applying he is greatly handicapped, and both he and the shop suffer.

After suitable and promising material is picked and trained for the welding gang there are many other things that still remain for the management of the shop to do for the welders, if a contented gang is to be secured and, may we add, only from a centented gang of welders will the best and cheapest, and generally satisfactory work, be secured. To quote again from the experience of a shop employing over one hundred welders on all welded tank work. This particular shop, after changing the size of some of their standard tanks found the costs creeping up, due to rejections and rewelding on account of leaks discovered when testing on the final inspection. The cause was at first quite mysterious, but a little study showed that the change in size of the tanks without any change in the working arrangements of the welders was causing the welding to be done in a most awkward position. Consequently, the welders, who were working on piece work, tired more easily and when tired their condition showed up in the quality of the work produced. A few simple changes, allowing the welders to work in more comfortable positions, and placing the work so that it was more accessible together with the establishing of a few regulations concerning what was and what was not acceptable welding, and the thorough understanding of these rules by the welders corrected the troubles and saved the day for welding in that shop. The moral is don't take the welding for granted and look upon it as so simple as not to warrant the intensive study of each minute detail, for only by the study, and establishment of absolute correctness of detail will the welding operations give back to the shop all of the remarkable advantages inherent in the process when correctly applied.

Up to this point in this paper no particular reference has been made to any other features that must be given consideration, than the mechanics of the actual welding operations and the behavior of the weld and parent metals under different heating and cooling conditions. We, however, cannot neglect in any study of welding operations where production problems are met, to give some thought to the attitude of the welder himself. If he considers himself abused or ill-treated, his attitude may make or break the very best mechanical arrangement and ruin a correctly designed welding job. In this respect he is no different from any other skillful artisan in other trades or occupations. The welder, frequently suffers at the hands of his employer because of his employer's lack of comprehension of welding and the ease or arduousness of many of the jobs assigned the welder. For example, we have seen an artificial set up cause unending trouble for the shop management through the concealed dissatisfaction of the welders. In a large shop where tanks and boilers were being manufactured all of the various fabricating operations were conducted on a piece-work

basis, and, of course, this system extended to the welding operations. Rates were established on a peculiar basis so that on certain jobs a good welder could "kill the job," work about as he pleased and still make his rate easily, while on other very important jobs it was practically impossible for the welder working as hard as he was able, to make a fair day's pay. The result was that on the underpaid job the work was slighted to make high speeds, the welder only partly fused the parent metal of the sheet, melting the welding rod as fast as he could and forcing it to run over the partially heated sheets. By this procedure there was a slight adhesion, but no real fusion between the deposited metal and the parent metal, therefore, there was no real weld. When the job was finally tested many leaks were found, rejections were high and costs mounted because of the rewelding, rehandling and retesting required, and sometimes the leaks were of such a nature that they could not be repaired, and the entire tank had to be scraped. It is generally recognized by all interested in industrial management that the basis of remuneration is one of the fundamental conditions that must be correctly established if piecework systems are to succeed and accomplish for the management what is expected of them. We are calling attention to this condition as it exists in connection with piecework rates as they affect welding, and point out that welding can suffer more from the injudicious application of piecework rates than practically any other common shop operation, because while the common shop operations are quite generally understood by the shop officials and cost accounting department, welding generally is a closed book, not understood and frequently looked upon as a very easy simple sort of thing that does not require any particular study and which does not have any technical or engineering problems worthy of serious study, except possibly those relating to pure research.

Of course, everyone in a gathering of this sort acquainted with welding realizes and appreciates what an involved and interrelated group of conditions must be settled before a really good production welding job can be planned, and above all, before a suitable piecework system can be established, but until the officials in control of the shops doing welding appreciate this and give the welding applications good sound engineering study, we are going to continue to have these unfounded complaints where the welding as such is condemned because of the ignorance of those who have used it improperly.

To continue the story of the shop having the trouble. Simple steps, obvious to those who thoroughly understand welding problems and conditions, were taken and today welding in that shop is an unqualified success.

In this paper on the Gas Welding of Light Gage Pressure Tanks, we have tried to cover the principal mechanical problems of the sizing and forming of the material as well as the mechanics of what constitutes good welding practice. Further, as we have

pointed out, there are personnel problems that must be taken into account along with the mechanical problems if good commercial welding is to be the rule in the shop instead of the exception. On account of the very great extent of the subject that we have attempted to cover, there are many topics that, while presenting interesting and involved problems and worthy of serious study, we have passed over lightly and treated as if unimportant. There may also be many other items referred to that appear trivial and probably quite abstract. We, however, in closing cannot emphasize too strongly the fact that while many of the items referred to may in themselves be rather abstract and unimportant, but taken as a whole are the very real and concrete factors that assume major importance, worthy of the undivided attention of the ablest engineers and executives, for in their correct solution all vexations of welding vanish and the process gives to the shop all the benefits of modern, up-to-date production and insure gratifying fianancial returns.

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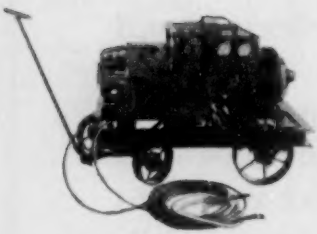

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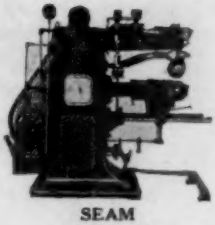

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Instructions for Beginners in Gas Welding and Cutting

Compiled by the Educational Committee of the American Welding Society

OCTOBER, 1927

Published by the

AMERICAN WELDING SOCIETY

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GAS WELDING and CUTTING

Instructions for Beginners in Gas Welding and Cutting

Compiled by the Educational Committee of the American Welding Society

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PREFACE

The three most important characteristics of a successful training program are: (1) a selected group of learners, (2) an occupationally competent instructor who has been trained in the art of teaching, and (3) functioning subject matter.

The American Welding Society has been engaged for a number of years in an attempt to promote the art of fusion welding through an adequate supply of competent welders. Several years ago it published in bulletin form an analysis of training courses for gas welders and for arc welders. These courses were prepared by representative committees, the members of which gave freely of their time and effort to the completion of these reports. These reports are known as Bulletin No. 4, Training Course for Oxy-Acetylene Welders, and Bulletin No. 7, Training Course for Electric Arc Welders.

More recently several sub-committees were created under the chairmanship of Mr. E. H. Ewertz for the purpose of preparing manuscripts on the fundamentals of welding and formulating the work of both committees into a manuscript which will serve as an authentic and up-to-date text for the training of welders.

The work of this Educational Committee was divided into four parts as follows:

Training Gas Welders and Cutters
Training Arc Welders
Training Resistance Welders.
Training Thermit Welders.

Each of these manuscripts was prepared by a sub-committee, the membership of which have endeavored to outline the latest and most successful practices in the welding process considered. This part deals with GAS WELDING AND CUTTING.

The American Welding Society is especially indebted to Mr. F. E. Rogers of the Air Reduction Sales Company, and to Mr. L. E. Ogden of the Oxweld Acetylene Company, for the manuscript on gas welding and cutting; to Mr. C. J. Holslag of the Electric Arc Cutting & Welding Company, and Mr. W. L. Warner of the General Electric Company, for the part dealing with arc welding; to Mr. H. A. Woofter of the Swift Electric Welding Company, for the part on resistance welding; and to Mr. W. R. Hulbert of the Metal and Thermit Corporation, for the part on thermit welding.

The Society is also indebted to Mr. James W. Owens, Director of Welding of the Newport News Shipbuilding and Dry Dock Company and Chairman of the Nomenclature, Definitions and Symbols Committee of the Society for his editorial work in connection with the nomenclature used in the manuscript.

Executive Committee

E. H. Ewertz, Consulting Engineer, 50 Church St., N. Y.
J. C. Wright, Federal Board for Vocational Education, Washington, D. C.
F. E. Rogers, Air Reduction Sales Company, 342 Madison Avenue, New York, N. Y.
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W. L. Warner, General Electric Company, Schenectady, N. Y.
L. E. Ogden, Oxweld Acetylene Company, 30 East 42nd Street, N. Y.

The manuscript presents the best knowledge available, not only from the welding standpoint but also from the standpoint of experience in preparing subject matter for training courses. All welding schools, both public and private, are urged to give it the most careful consideration and to use it as a text and guide in laying out proper courses for the training of welders. The arrangement of the subject matter is flexible and can be easily adapted to programs organized for the purpose of preparing new workers to enter this industry, as well as for the purpose of extending the technical education and skill of those already employed as welders.

Gas Welding and Cutting

Information and Instructions for Beginners in the Use of the Gas Welding and Cutting Processes

COMPILED BY THE EDUCATIONAL COMMITTEE OF THE AMERICAN WELDING SOCIETY

CHAPTER I

THE FUNDAMENTALS OF GAS WELDING

NOTE: It will be understood that oxygen and acetylene are the gases used in gas welding and cutting, unless otherwise stated. The metals welded or cut will also be understood to be low and medium steel plates and shapes unless otherwise stated.

THE CONSTRUCTION AND OPERATION OF THE TORCH

An oxy-acetylene welding torch is an instrument that thoroughly mixes the two gases, oxygen and acetylene, in the proper amounts and that permits easy adjustment and regulation of the flame and the application of the intense heat so produced to the edges of the metal parts to be joined so that they will be brought to the molten or fluid state quickly, caused to fuse or to run together and upon cooling result in a joint or union having strength and chemical qualities approximately the same as those of the original parts. Such an instrument is necessarily one of exact manufacturing limits, demanding the same care and attention as any other precision instrument.

Fig. 1. Illustration of pressure torch

Broadly speaking, there are two types of torches—pressure and low pressure—differing somewhat in principle and design. In the pressure type of torch, both acetylene and oxygen are supplied to the torch under appreciable pressures of 1 lb. or more, approximating equal pressures in some types, and with lower acetylene than oxygen pressure in other types, the pressures being increased for each larger size of tip used. (The number of pounds pressure required for welding any one particular thickness of metal depends upon the make of the torch used and is set forth in a chart furnished by the manufacturer). These two pressures are produced independent of each other. They are fixed and con-

trolled by the regulators on the oxygen and acetylene cylinders, or on the acetylene generator, if generated acetylene is used. The mixture of the gases usually takes place in the handle or head part of the torch. This bringing together of the two gases thoroughly mixes them before they burn at the end of the tip.

In the low pressure or injector type of torch, Fig. No. 2, the oxygen only is under pressure, the acetylene is under low pressure, less than a pound per square inch. The mixing chamber is usually located in the head part of the torch and is made on the same principle as an ordinary steam water injector of a steam power boiler—a cone or nozzle containing a relatively small outlet hole through which the oxygen under pressure is forced. This gives it

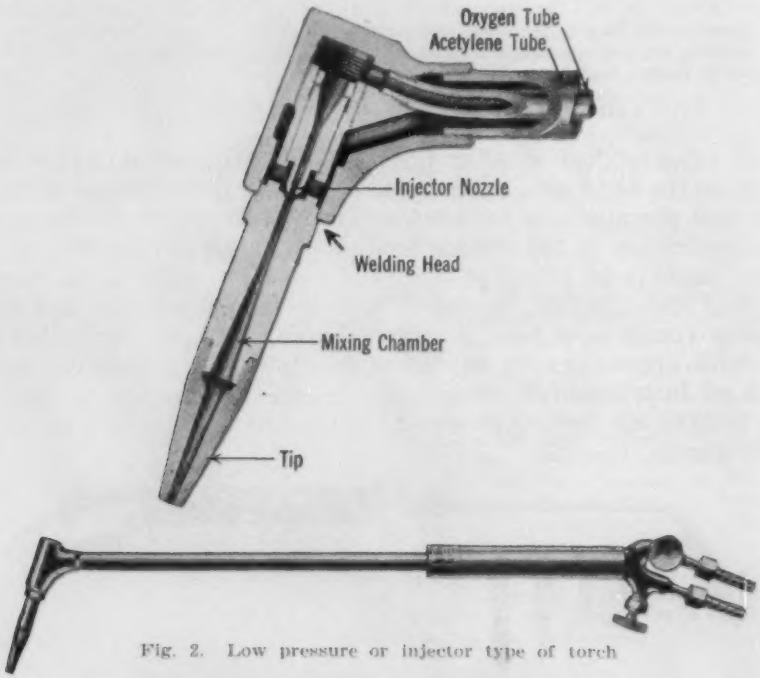


Fig. 2. Low pressure or injector type of torch

a high velocity which sets up or makes a vacuum effect that draws the low pressure acetylene into the mixture. In other words, the volume of acetylene going into the mixture is dependent upon the velocity, and not the volume, of oxygen. If the pressure of the oxygen changes, the amount of acetylene drawn into the mixture will change, likewise, thus holding the flame as set by the operator.

Welding torches are usually made of brass or bronze forgings, tubes and machined parts, except the tip which is made of hard copper so as to withstand the very high heat of welding. This tip can be replaced at low cost when it is damaged or burned out without the need of buying a whole new torch or even a new head that would cost considerably more because of the machine work on it.

Each torch is supplied with several different sizes of tips. Tips having large holes are used for heavy work and those having small holes are used for sheet metal. In addition, some torches have several different sizes of mixing chambers or mixing nozzles. Keeping the hole sizes and gas outlets of the tip, mixers and injectors clean and unchanged in size no matter how old the torch may be, is a very important matter. This statement is true not only of the parts named, but also of the various needle valves, hose connections and in fact every part of the torch and even the hose itself. Every opening should be clean to permit the passage of

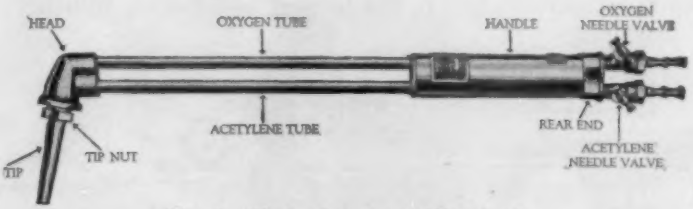


Fig. 3. Parts of a gas welding torch

the proper volume of gas without hindrance or tendency toward slowing it up. On the other hand, great care must be taken to avoid enlarging passages by carelessness in cleaning. The primary objective is to deliver the gases to the flame in the volume required to do the work, and at the same time at a sufficiently high velocity or speed of flow so as to prevent the burning of the flame back into the mixing point of the gases, in other words, so as to prevent a "backfire." If the size of the holes is cut down the volume is decreased, and if it is enlarged the velocity or speed of flow is decreased.

The hole sizes of the copper tips are determined with particular care. After considerable use they often become caked with carbon and with small pieces of metal or oxide from the parts being welded.

The first idea of the careless or untrained operator is to ream out the tip with a file tang. This procedure cannot be criticised too severely since the hard file not only enlarges the hole but also often leaves a scar or groove that produces a ragged or lop-sided flame. When it becomes necessary to clean a tip, the welder should use a wire made of copper, brass or some other composition metal that is softer than the hard copper of the tip.

In both types of torches the oxygen and acetylene gases reach the mixing chamber and tip by means of two separate passages or tubes that lead from the respective hose connection through the handle of the torch. The flow of each gas is controlled by a needle valve located near the hose connection.

Sometimes dust, particles of the rubber hose, or other foreign matter find their way into the interior of the torch and stop up the gas passages. To prevent this from happening the operator should

blow through the hose before connecting it to the torch. Whenever a torch becomes stopped up in this way the operator should disconnect the hose from the torch and then slip the oxygen hose over the end of the tip and blow oxygen backward through the torch at about 20 lb. pressure, first with the acetylene valve open and then the oxygen valve open. The blow of gas backward under this pressure will usually clear the passageways.

The welder requires a small flame and little heat for welding thin gage metals and a large flame and much heat when welding heavy sections. This is the reason for the separable interchangeable tips furnished by the torch manufacturers in several sizes ranging from the smallest to the largest practicable to use.

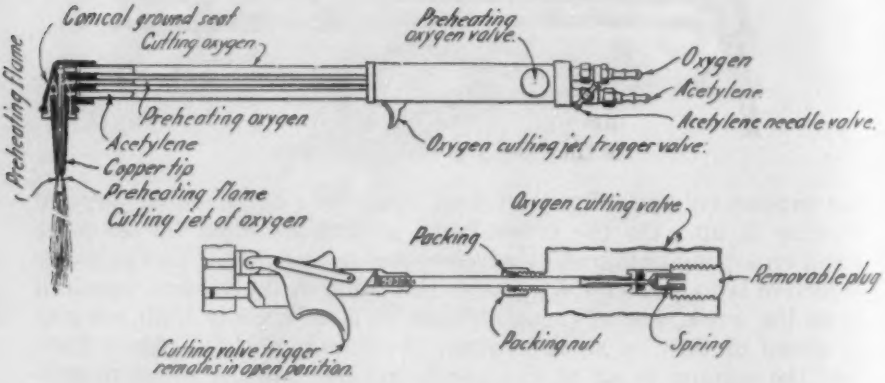


Fig. 4. Illustration of cutting torch with longitudinal section showing parts

Tables of tip sizes to be used with various thicknesses of metal from 1/32 in. to 3/4 or 1 in., are furnished by the manufacturers as a guide.

The size of tip to be used depends on the nature of the job and the skill of the welder. A skilled welder, especially one working on production jobs, often uses a tip two or three sizes larger than another welder of less skill and experience could use on ordinary repair jobs of the same metal thickness.

A tip too small for the job slows down production and is wasteful of time and gas as the proportion of heat lost by radiation is larger than with the tip of correct size. A tip too large in the hands of an unskilled welder is likely to produce unsatisfactory, uneven welding due to lack of control. Oxidized and poorly fused welds are results of using tips too large or too small for the job, unless the welder has the experience and skill to apply the heat properly.

The kind of metal to be welded is also a factor which enters into the choice of tip. Thus copper requires the use of tips one or two sizes larger than steel of the same gage, owing to the more rapid heat transfer and radiation of copper.

gas passages. To prevent this from happening the operator should

The cutting torch, Fig. No. 4, differs from the welding torch in that in addition to having the oxy-acetylene heating flame it also has another gas stream of pure oxygen under high pressure which does the cutting after the metal is raised to the ignition point by the heating flame.

The principle of oxy-acetylene cutting is quite simple. After a

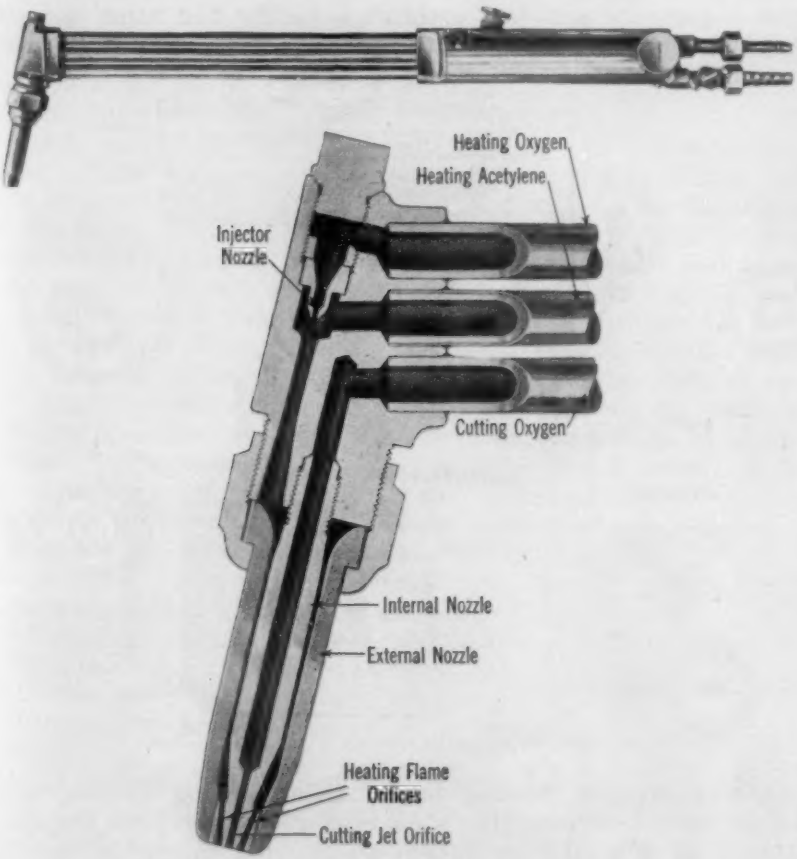


Fig. 5. A cutting torch with head shown in section

small spot of metal has been heated red hot, a jet of oxygen is shot against it. The iron and oxygen combine to form iron oxide, thus burning a narrow slit or "kerf" in the steel. It is a chemical process pure and simple and should not be confused with mere melting. As a matter of fact, the chemical process is a very rapid form of rusting, the every-day form of which is familiar to everyone.

The oxygen cutting jet is maintained under sufficient pressure to blow away the oxide as fast as it is formed so that the slot is kept open. For heating the metal red hot, the oxy-acetylene flame

rapid heat transfer and radiation of copper.

is used. It is identically the same kind of flame that is used for welding. The flame, however, is divided into a number of jets or flames, varying from two to six, Fig. No. 5, depending on whether speed or smoothness of cut is more desired. Usually the cutting jet of oxygen is circled by these preheating flames, thus enabling the cut to be made in any direction.

Like the welding torch, the cutting torch is also made in two types — pressure and low pressure — having the same general design in the placing of mixers, injectors, tips, etc., as the cor-

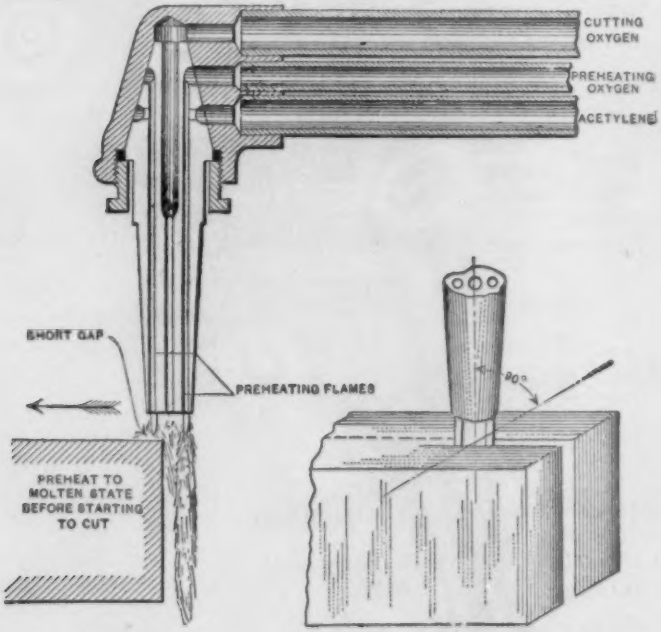


Fig. 6. The cutting torch starting a cut and in action

responding type of welding torch. Some cutting torches have solid or one-piece copper tips while others have two-piece tips consisting of an internal brass tip and an external copper tip that fits over the inner one like a sleeve. The tips of a cutting torch or the tips of a welding torch should never be tightened while they are hot because the pull upon cooling is very likely to strip the threads.

Cutting torches, like welding torches, have two needle valves on the handle near the hose connections, one for oxygen, one for acetylene. In addition, the cutting torch has another valve further forward on the handle, as shown in Fig. No. 4. When this valve is open, the cutting jet of high-pressure oxygen flows out through the central opening in the tip. This cutting valve, as it is called, usually has a latch or other arrangement so that it can be locked in open position for continuous cutting.

In selecting a torch, either welding or cutting, it is always well

kept open. For heating the metal red hot, the oxy-acetylene flame

to consider the weight and balance. It should be of such weight and construction as to withstand the rough use and abuse that is usually given a torch, but at the same time should not be so heavy that it will tire the operator. Those torches with large and heavy heads, which throw the balance forward, are usually hard to handle and very tiresome to the operator, especially when the work is on production and the torch is used for long periods at a time.

The Construction and Operation of Pressure Regulators and Safety Devices

Regulators.—A regulator, or reducing valve as it is sometimes called, is used to reduce the pressure of the gas flowing from the cylinder down to any wanted working pressure, and for delivering the gas to the torch not only at constant pressure but also in constant volume. They all work with a diaphragm controlled movement and are all very much alike. The diaphragm may be made of metal or special rubber composition. The gas enters the body of the regulator through a small nozzle, that closes when the regulator valve is caused to press against a composition disk or seat and exerts pressure outward on the diaphragm. An opposite pressure is exerted on the other side of the diaphragm by a wire spring. This pressure is regulated by an adjusting screw. When the adjusting screw is turned in it moves the disk seat away from the nozzle (in some regulators the seat is stationary and the nozzle is moved away) and permits gas to enter the regulator, but as the gas pressure builds up on the diaphragm the disk seat is forced back against the nozzle and the gas passage is closed for a moment and then this action takes place over and over again as long as the torch is being used. Hence, a constant balance is struck. The regulator can be set to deliver any desired available pressure by merely turning the adjusting screw in or out a variable number of turns.

It is evident that the cylinder valve should never be opened while the adjusting screw is turned in, that is, while the seat is away from the nozzle, otherwise all the pressure in the cylinder would be suddenly transmitted against the diaphragm and the valve seat would be forced against the nozzle with such a sudden impact that it would either break the disk or rupture the diaphragm. The composition of the disk seat is an important matter. Hard rubber, horn, casenite, galalith, bakelite, etc., is used with success. The seat should be soft enough to take an impression of the nozzle and thus seat tightly, yet not so soft that the nozzle will cut it. On the one hand it should be sufficiently hard and tough so that it will not be marred easily by grit that finds its way into the inside of the regulator, but, on the other hand, not so hard that it is brittle and easily broken. The diaphragm is composed of either a highly tempered non-rusting metal alloy or of

In selecting a torch, either welding or cutting, it is always well

rubberized fabric. The former has the advantages of long life and non-inflammability with the disadvantages of being less sensitive while the latter has a shorter life but is much more flexible and sensitive and can easily be replaced.

Regulating Mechanism.—In cross section, a regulator of the nozzle type appears as in Fig. No. 7a. High pressure oxygen enters the regulator through the inlet connection *A*.* There are two branches in the high pressure chamber *B*, one leading to the high pressure gage *C*, the other to the valve nozzle *D*.

When the pressure adjusting screw *G* is released by turning to the left, the valve seat *E* is held tight against the valve nozzle *D* by means of the valve spring *F*. This spring is strong enough to resist the pressure of the oxygen in the high pressure chamber, hence left to itself it closes the valve and no gas passes.

As the pressure adjusting screw is turned to the right it compresses the pressure adjusting spring *H*. From the sketch it will be evident that as spring *H* is compressed, it will force the rubber diaphragm *I* against the end of the valve sleeve *J*. As the valve sleeves is forced in against the compression of valve spring *F*, the valve seat *E* moves away from the valve nozzle *D*, opening the valve. Oxygen then flows from the high pressure source into the low pressure chamber *K*, and through hose connection *M* to the torch.

Assume for the moment that the torch valves are closed. Pressure builds up in the low pressure chamber *K* and reacts on the diaphragm, forcing it away from contact with the valve sleeve. As soon as this happens, valve spring *F* closes the high pressure valve. Of course spring *H* is now held in compression by the pressure of the oxygen in *K* on the diaphragm *I*. As soon the pressure in *K* is reduced slightly by opening the valve at the torch handle, thus allowing gas to escape from *K*, spring *H* again forces the diaphragm against the valve sleeve and reopens the high pressure valve.

This reciprocal or balanced action constitutes the regulating mechanism. The pressure adjusting handle can be screwed in until the desired working pressure is shown on the working pressure gage (which is in connection with chamber *K*, but does not show in Fig. No. 7a). Once set, the action of spring *H* and diaphragm *I* will keep constant the pressure of the oxygen passing through hose connection *I* to the torch.

A regulator of the stem type having a positive closing mechanism is shown in part section in Fig. No. 8. Oxygen from the cylinder enters the regulator through inlet connection *A*, passing to the high pressure chamber *B*. *B* is connected with the high pressure gage *C*, through the opening just visible in the upper part of *B*. It will be noted that the valve stem *D* projects into the high pres-

*The description given here is of an oxygen regulator, but an acetylene regulator is of essentially the same construction.

posed of either a highly tempered non-rusting metal alloy or of

sure chamber *B* so that the high pressure of the oxygen will tend to force the valve stem against the valve seat *E*.

When the adjusting screw *G* is screwed in, compressing the

Oxygen regulator Acetylene regulator

Fig. 7. Typical regulators

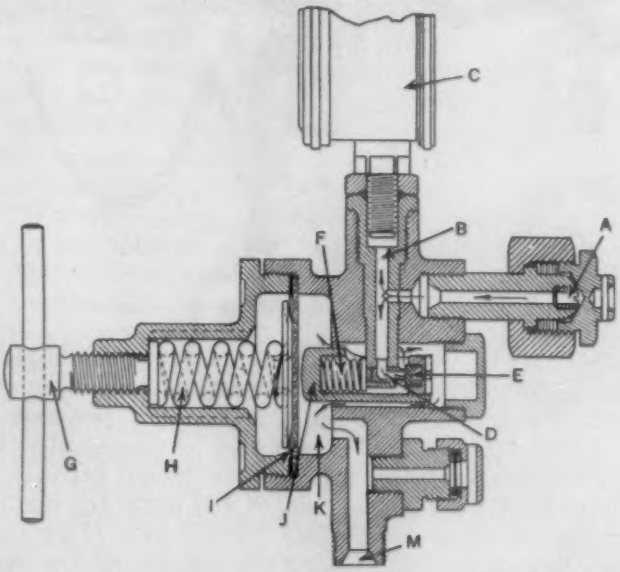


Fig. 7-A. Cross section of a nozzle type regulator

spring *H*, the motion is transmitted to diaphragm *I* and the attached valve stem *D*. As the stem head moves away from seat *E*,

of essentially the same construction.

oxygen passes through the annular opening around the stem into the low pressure chamber *K*, thence through the outlet or hose connection *M* to the torch. Working pressure is shown on low pressure gage *L*.

As with the nozzle type mechanism, spring *H* and diaphragm *I* control and regulate the working pressure.

The better and higher priced regulators are fitted with two pressure-showing gages, one for showing the pressure in the cylinder and the other for showing the reduced or working pressure going

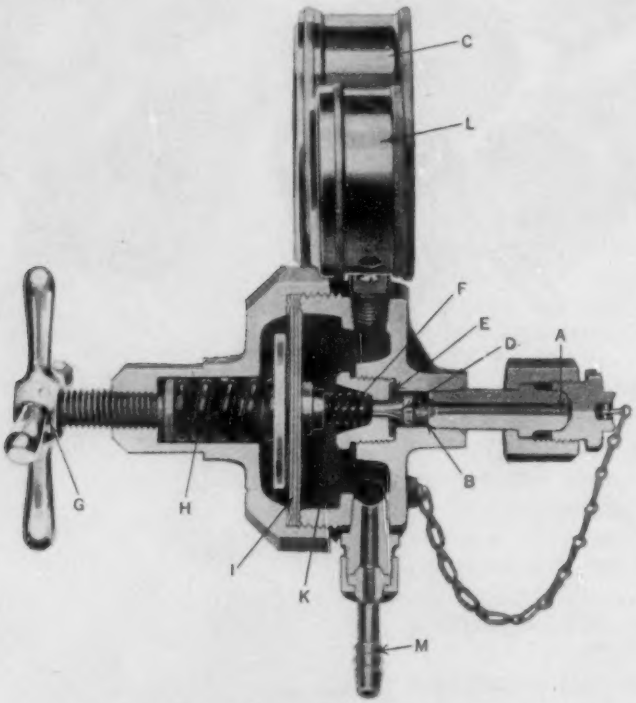


Fig. 8. Cross section of stem type regulator

through the hose to the torch. If the seating mechanism is not dependable in its movement or if the seat becomes worn or marred the regulator will leak, thus causing the low pressure gage to "creep." Creeping to a small extent may be disregarded, but when it occurs in any great amount it becomes a danger because too much pressure may build up in the regulator and burst the diaphragm or injure the low pressure gage. This trouble may often be entirely avoided by the simple plan of carefully taking out the seat holder and placing a piece of paper under the seat or by turning the seat over so the other side will make contact against the nozzle. Where these methods do not stop the leak a new seat should be used.

The most important safety precaution, never to be neglected

tached valve stem *D*. As the stem head moves away from seat *E*,

when turning on cylinder pressure, is that of having the adjusting screw released before opening the cylinder valve so that the high-pressure gas is restrained at the nozzle and not permitted to enter suddenly the low-pressure chamber. A large part of regulator valve troubles is due to careless manipulation in this respect. In the same way diaphragms are ruptured and valve seats injured, thus making repairs necessary.

A safety disk or valve prevents pressures in the diaphragm chamber from building up to a dangerous point. The safety disk "blows" when the pressure becomes dangerous and relieves the excessive pressure. If "blown" by over-pressure, the disk must be replaced by a standardized safety disk and not by a makeshift metal disk. Before replacing a blown disk the cause of the trouble should be found and remedied.

Oxygen and acetylene regulators are of the same general type and construction, but the acetylene regulator, since it is required to withstand cylinder pressures of only 250 or 300 lb., is of much lighter construction. Oil, grease or any oily matter should never be used on a torch, an oxygen regulator nor on an oxygen cylinder valve. Oil in contact with oxygen will burst into flame and cause damage and perhaps injure the welder or some fellow workman.

As has already been stated, torches and regulators are precision instruments. Their proper repair requires special and highly accurate tools. Minor repairs and adjustments may be made by the user, but where troubles occur which require major repairs, the apparatus should be sent to the manufacturer, since he and he only is equipped to make these repairs properly. This procedure will always prove to be the most economical in the end.

Pressure Gages.—Pressure gages used with oxy-acetylene welding and cutting apparatus generally employ the Bourdon tube as the primary operating element. It is a curved tube of elliptical cross section sealed at one end and connected to the gas chamber at the other. Internal pressure causes the tube to straighten. The movement of the outer or sealed end is multiplied by a mechanical device so that a small tube movement is translated into a large relative movement of the indicating hand.

Pressure gages are calibrated by testing them in comparison with standardized gages, and the graduations on the face are usually made to indicate as clearly as possible the subdivisions of the scale within the working limits.

The difference between high-pressure and low-pressure gages is chiefly in the graduations on the face and the strength of the working parts. High-pressure gages used with oxygen pressure regulators, however, are so made that in case of rupture of the Bourdon tube a flexible member in the gage casing will release the gas pressure and thus avoid bursting the body and shattering the glass.

Welding operators are cautioned to open cylinder valves slowly,

especially the valves of oxygen cylinders, sudden application of high pressure may injure or rupture the high pressure gage Bourdon tube and necessitate expensive repairs.

Safety Devices.—Flashback chambers are devices to prevent the propagation of flame through acetylene pipe lines. They generally employ a water seal, the incoming gases bubbling up through water. In case of a flashback the water prevents the propagation of the flame further.

The pressure regulator is an excellent flashback prevention device. Very rarely does a flashback pass through a pressure regulator.

The safety disk or valve, previously referred to, prevents building up dangerous pressures in the pressure regulator. These disks usually are of composite structure which will uniformly yield when the pressure exceeds the maximum predetermined safe working pressure.

Troubles Liable to Occur in Torch and Regulator and How to Recognize and Remedy Them

Leaky Handle Valves.—Leaky control or needle valves on a torch may be recognized when the gas continues to flow from the tip after the valves are closed. If the acetylene valve leaks, a flame will persist at the tip when the torch is shut down. A simple and quick test to determine the presence of small leaks is made by closing the torch valves and the cylinder valves. If the working-pressure gage in either regulator drops quickly, a leaky valve, hose connections or hose is indicated. Leaky valves are potentially dangerous and should be immediately repaired.

Leaky Tips, Causes and How to Avoid.—Leaky tips usually result from overheating and from a careless assembly. The welder must handle the tips carefully, avoid bruising the seats and clean the seats of any foreign matter before inserting them in the torch. Care in this respect and in avoiding overheating will minimize tip leakage and tend to eliminate it entirely.

Passages in Tip or Handle Stopped Up With Carbon or Other Foreign Matter.—Clogging of the tip and torch passages is due, generally, to two causes, backfires and foreign matter in the hose. New hose should be blown out before it is connected to the torch so as to clear it of all dust, bloom and other foreign matter. Hose that has been disconnected and stored should be blown out to dislodge sand, dirt and other foreign matter likely to clog the torch or tip before connecting it to the torch.

Proper Method of Cleaning Tips and Handle Passages.—Backfires cause carbon deposit and often these deposits are of considerable amount. To clean out these deposits the torch should be disconnected from the hose and the hose "blown out"; the tip should be removed from the torch and the torch blown to clear the passages; and the tip should be carefully cleaned, using a soft

welding operators are cautioned to open cylinder valves slowly,

copper wire for the purpose. For reasons already given, never use an iron or steel wire for cleaning a tip.

Grinding in Valves and Tips and Objections to the Practice.—Worn valves, seats and tip seats can seldom be corrected by grinding. The surfaces should be machined and reamed, using special tools. If a torch needs repairs requiring the reaming of the head, it should be sent to a repair shop having tools for this purpose. Worn control or needle valves generally can be replaced with new ones at less cost than the repair of the old ones.

Creeping of a Gage Due to Leaky or Fouled Seats.—If the working-pressure gage builds up a pressure quickly when the torch valves are closed and the adjusting screw is released, a leaky valve seat is indicated. Leaky seats are caused by improper handling, such as opening the cylinder valves without releasing the adjusting screw, by the presence of foreign matter, and by long continued use.

A leaky regulator valve should immediately be replaced, as neglect may result in an accident or in damage to the equipment.

How to Replace Seats.—Replacement of regulator valve seats varies with the make of regulator. Some regulators are designed so that the replacement of seats is a simple matter requiring ordinary tools such as vise and screwdriver only. Other regulators require dismantling the spring casing and diaphragm. The welder should rarely attempt to replace valve seats in the latter type of pressure regulator, nor should he try to replace seats in any regulator unless he appreciates fully the care required to insure proper replacement. No grease or oil can be used on the screws or parts of an oxygen regulator and the parts should never be handled with dirty or greasy fingers.

How to Check Gages for Accuracy.—Pressure gages are tested with a gage tester, using water as the medium. Steam gages are generally tested with a gage tester using oil. Oil cannot be used when testing oxygen gages, nor should it be used for testing any regulator for gas welding or cutting.

Effect of Buckled Diaphragm.—A buckled or distorted metal diaphragm will not register properly and should be replaced by a new one.

How to Apply New Diaphragm.—Pressure gages are made of both metal and rubber diaphragms. Metal diaphragms are generally soldered to the valve case and replacement is a factory or special repair shop job. Rubber diaphragms can be replaced in the welding shop, taking care the parts are properly assembled and the spring case is screwed down tightly. The regulator casing should be tested for leaks before using it.

Broken, Buckled or Leaky Gage Tube.—Defective gage tubes are indicated by improper action and the presence of leaks. The repair of gage tubes is a factory job, seldom to be undertaken in the

ordinary repair shop, except in emergencies. When defective the gage should be removed and replaced with another, taking care that it is the correct type and that the screw threads permit of a tight fit.

When to Send Equipment to Factory or Service Station for Repairs.—Torches, regulators and other equipment requiring expert service should always be sent to an authorized service station or to the manufacturer when in doubt as to the ability of the welder to make the necessary repairs.

Extra or emergency equipment should be provided for use while defective apparatus is being repaired at the factory. Shops having tool rooms and expert mechanics can often have one of their men trained to repair apparatus by the traveling representative of the manufacturer.

Construction and Handling of Oxygen and Acetylene Tanks or Cylinders

Oxygen Tanks.—Tanks for storing and shipping compressed oxygen are seamless drawn cylinders of special heat-treated steel. These are made to stand a test pressure much above their normal working pressure. They must comply with regulations of the Interstate Commerce Commission and specifications of other regulatory bodies as well as local rules and ordinances.

Regulations require that these tanks be tested from time to time and that the date of the last test be stamped on each tank. Any cylinder not meeting these test requirements is rejected and thrown out of service. Tanks also carry several other markings, some being the manufacturer's private marks of identification and other marks prescribed by the various governmental bodies. *It is against the law to change or erase any of these stamped markings.*

Each oxygen tank has a special high pressure valve and each large manufacturer has his own special valve. All of the valves operate in the same way and in general a standard thread outlet is used. Not all valves must be opened full to prevent leakage around the valve stem, but the rule to open all valves full, should be observed with all oxygen tanks.

Oxygen tank valves are usually of cast brass or bronze. They are opened and closed with a handwheel at the top. The outlet is located on the side of the top fitting and consists of a male connection with right-hand threads. These threads are used so that fuel gas regulators can not be attached to oxygen tanks, since all connections on fuel gas regulators have left-hand threads.

In each valve there is a safety plug to provide for exhausting the tank of its contents when an explosion due to fire or excessive pressure is likely to occur. Some of these safety plugs are made of a fusible alloy which melts when the temperature reaches a certain point and allows the oxygen to escape, while others are fitted with a disk which when the pressure in the tank becomes too high

pair of gage tubes is a factory job, seldom to be undertaken in the

ruptures or breaks and lets the oxygen escape, regardless of how this pressure is built up.

Valve parts are protected by an iron cap which screws on a shoulder on the tank. This cap must be removed before the regulator can be attached, and it should not be lost. When empty or full tanks are being stored around the shop and when empty tanks are returned to the manufacturer, this valve cap should be on. Most manufacturers make a charge of $1.00 for each cap lost.

Oxygen is compressed into cylinders or tanks at a pressure from 1800 or 2000 lb. per square inch at 70 deg. F. (degrees Fahrenheit). The most common tank capacities are 100 to 110 cu. ft. for the small size, and 200 to 220 cu. ft. for the larger and more common size. In general, where a pressure of 1800 lb. per square inch is used, tanks have a capacity of 100 and 200 cu. ft., and where the pressure is 2000 lb. capacities are 110 and 220 cu. ft., respectively.

The pressure in oxygen cylinders changes a little with temperature. The pressure increases when the temperature rises, and falls when the temperature falls. For example, suppose a full tank of oxygen showing 2,000 lb. pressure is moved from the welding room where the temperature is about 70 deg. out into the yard and allowed to stand around for a few hours on a cold day when the thermometer is around zero. The pressure shown will then be only about 1650 lb. This does not mean that any oxygen has been lost. The same number of cubic feet are in the tank but they do not give as much pressure at the lower temperature.

This variation does not in any way affect the normal number of cubic feet of oxygen in the tank. Where pressure is very low because the tank has been standing out-of-doors in cold weather, this pressure can be brought up to normal by moving the tank indoors and allowing it to stand for four or five hours. There is no advantage in doing this, however, since the temperature of oxygen in the tank does not in any way affect either the temperature of the flame or the volume of oxygen at the time it is consumed. Tanks should not, under any condition, be placed near stoves or boilers when cold in order to raise the temperature. When this is done, it is possible that the pressure will be increased beyond the safety limit or that the fusible safety-plug will be heated to the fusing point and all the oxygen in the tank lost.

A special warning in connection with the use of oxygen tanks bears repeating many times. *Do not use oil or grease* of any kind around oxygen tanks, valves, regulators or gages. In the presence of oxygen under pressure, oil will catch fire and burn violently. This warning should always be heeded. An operator with greasy hands should not handle tanks of oxygen until his hands have been thoroughly washed and oily or greasy gloves, of course, should never be used.

Before attaching the regulator to an oxygen tank, the valve should be opened slightly to blow out any dust that might have collected in the outlet. This is called "cracking" the valve, and is

done by simply giving the handwheel a quick half-turn and immediately closing it tight.

Valves should be opened by hand only, a wrench should never be used. There are several wrenches on the market which are claimed to be useful for opening oxygen tank valves, but it is recommended that neither these nor any type of home-made wrench be employed. If the valve can not be opened by hand or if the handwheel is twisted off or the valve stem damaged, the cylinder should be immediately set aside, tagged so that it can be recognized as having a defective valve, and returned to the manufacturer.

No oil or other lubricant should ever be used to aid in operating or closing oxygen tank valves. If the valve is found to be leaky when the tank is received, or if, during use, it develops a leak that will not stop when the valve is opened as far as it will go, the cylinder should be placed out-of-doors, the valve opened slightly and the oxygen allowed to blow off into the air. Such a tank should be tagged "Defective" and returned to the manufacturer promptly.

In attaching regulators, the connecting nut should screw on the tank connection freely and easily and should be drawn up tight with the wrench provided with the apparatus. If there is any difficulty the regulator should be inspected to make sure that a fuel gas regulator has not been picked up by mistake.

In beginning to use oxygen from the tank, open the valve very slowly. This will prevent a sudden release of the high pressure against the regulator diaphragm which might damage the regulator. As a general rule oxygen valves should be opened as far as they will go to prevent leaking around the valve stem.

Lighting the Torch and Adjusting the Flame.—Open the acetylene needle valve—the lower valve on the torch—and light the gas with the spark lighter. Acetylene always burns with a smoky flame having the general appearance shown at *A*, Fig. No. 9. The operator should now open the oxygen needle valve slowly (the upper needle valve) and the flame will change in appearance. If the oxygen is in condition to give complete combustion the flame will have the appearance shown at *B* in Fig. No. 9. A flame having this appearance is a carbonizing flame, that is, it has an excess of acetylene and hence causes carbon. The operator should now open the oxygen valve a little wider and produce the *neutral flame* shown at *B* in Fig. No. 9. The bulb or cone of incandescent gas is now clearly defined. This flame is the one generally employed in welding, and it is a part of the welder's education, to be able to secure and recognize this flame quickly and with certainty.

If too much oxygen is admitted through the needle valve the flame will shorten and have the appearance shown at *C* in Fig. No. 9. The cone is shortened thus showing that an excess of oxygen is being used and that the flame is an oxidizing flame. This flame should be avoided as it tends to make porous and brittle welds.

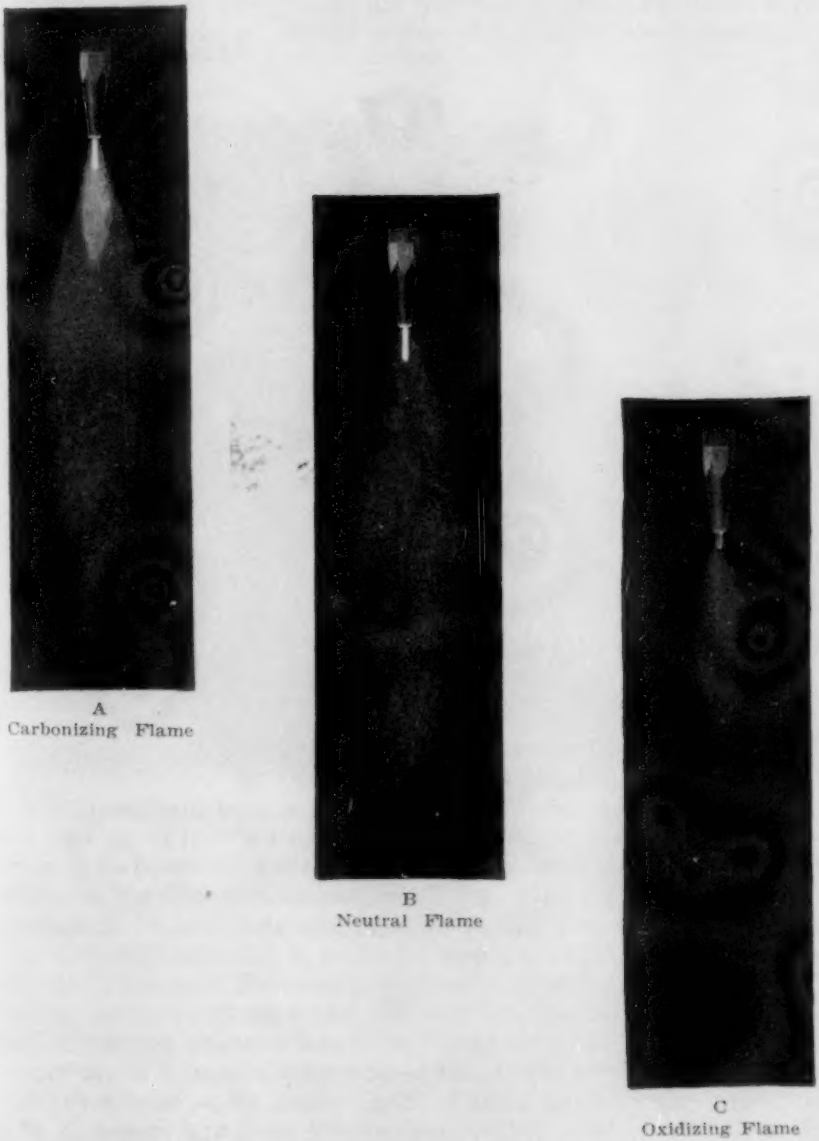
When the work is done or stopped for any length of time the valves should be closed tightly and the regulators and torch ad-

collected in the outlet. This is called "cracking" the valve, and is

justed to release the pressure in them. When a tank is empty, close the valve tightly and put on the valve cap.

Full or empty oxygen tanks should be stored where they will not come in contact with oil or grease of any kind. They should also be kept away from stoves or boilers and should be put where they will not be knocked over and damaged.

While tanks are carefully designed so as to be safe under all



A
Carbonizing Flame

B
Neutral Flame

C
Oxidizing Flame

Fig. 9. Stages of welding—torch flame

ordinary conditions, they should be carefully and intelligently handled. Oxygen tanks should not be dropped or handled in any way that might dent them, and should not be used as rollers or supports. They should be kept away from preheating fires. When used for cutting, tanks should be out of the way so that the slag will not fall on the tank, on the valve or on the hose.

Oxygen tanks should never be lifted in a sling or by an electromagnet. If necessary to hoist them about with a crane use a box or a cradle, carefully protecting the tanks from falling. If a tank is damaged accidentally, the valves should be opened a little and

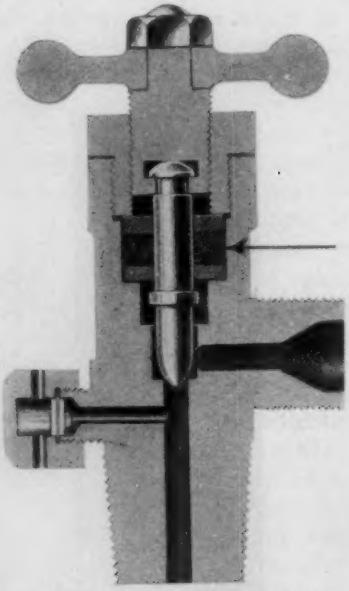


Fig. 10. Cross section of oxygen cylinder valve

the oxygen allowed to waste slowly. It should then be tagged "Defective" and returned to the manufacturer.

In using oxygen around the shop, it is a good practice either to have a place where tanks can be set against a wall or column and chained in an upright position, or to use them mounted on a handtruck made for this purpose. These precautions will prevent damage to the valves and loss of oxygen, and also prevent damage to the regulators and to the gages.

Oxygen tanks should be used in the order received from the manufacturer. Do not use first the latest tanks received, as this practice will be likely to result in rental charges for tanks held overtime. Empty tanks should be promptly returned to the manufacturers' distributing station from which they were originally shipped. Promptness in this regard will also save money by preventing unnecessary charges for rental.

Oxygen cylinders must have a valve especially designed to operate on high pressures. The valve shown in cross section in Fig. No. 10 illustrates typical valve used on oxygen cylinders. The valve has a double seat and operates either in the fully open or fully closed position, that is, the valve, when opened, should always be opened as far as it will go.

When the cylinder is not in use the iron cap shown in Fig. No. 11, should be screwed on the neck ring of the cylinder so as to protect the valve from damage.

Acetylene Tanks.—Acetylene tanks are quite different from those

Fig. 11. Acetylene and oxygen cylinders

used for oxygen. They consist of a steel tank or shell completely filled with a porous filler material. This filler, in turn, is saturated with a chemical solvent which absorbs the acetylene, holding it in solution until released in a gas form as it passes through the opening of the valve. The reasons for this complex structure are, first safety, and second, capacity. The porous filler prevents the spread of any flame within the cylinder, and the solvent provides for capacity without excessive pressures. Acetylene tanks are subject to regulations of the Interstate Commerce Commission and other governmental agencies, and to many local rules and ordinances. Each tank carries Interstate Commerce Commission markings in

addition to the manufacturer's identification marks. It is against the law to tamper with or to change these marks in any way.

Different makes of acetylene tanks vary considerably in shape and size. Some of them have a dished bottom and head, and in these the valve sits down in the recess at one end. Others are made with a rounded head somewhat similar to oxygen tanks and on these the valve is protected with a valve cap.

Acetylene tanks are made of larger diameter and less height than oxygen tanks to prevent them being easily overturned. The presence of a liquid in the tank makes it advisable always to use the tank in an upright position. If, for any reason, it is absolutely necessary to turn an acetylene tank down on its side when using gas, the valve end should be blocked up as much as possible.

Acetylene tank valves are made from brass or bronze castings. Some of them operate with a hand-wheel and others are opened by the use of a special *T*-handle wrench furnished by the manufacturer.

In tanks with dished ends, fusible safety plugs are fitted in both the head and the bottom. These exhaust the tank of its gas pressure when the temperature gets too high. Other types of tanks have a safety plug on the valve, together with additional plugs on the bottom.

Acetylene is of such nature that it cannot be compressed like oxygen. Therefore, tanks for acetylene are filled with a porous material which is saturated with a liquid having the property of absorbing many times its own volume of acetylene. The acetylene is dissolved in this liquid like sugar in coffee, except that it can be readily released as a gas when needed. This liquid gives off acetylene when the tank valve is opened. Because acetylene is dissolved and not just compressed it is not possible to tell the number of cubic feet of acetylene in the tank from the gauge pressure reading. Manufacturers of acetylene figure the volume from the weight of the gas in the tank on the basis of 14½ cu. ft. of acetylene for each pound difference between the charged and exhausted weight of the cylinder. Weighing, of course, must be done under conditions that will give very accurate reading.

To use acetylene the cap should be removed if the tank is fitted with one. Then the valve should be opened slightly or "cracked" as it is called, to blow out any dust that may be in the outlet. When the regulator is attached, the valve should be opened slowly. It is only necessary to open the valve about 1½ turns.

Tanks fitted with a valve employing a *T*-handle wrench should be used with the wrench in position so that the valve can be closed quickly if necessary.

When acetylene tanks have been transported or stored on their side, some of the liquid may escape when the valve is first opened. If this does not immediately stop, the valve should be closed and the tank allowed to stand on its end for about two hours. It should

then be possible to use the tank without losing any more of the liquid.

Acetylene tanks and valves are of sufficiently sturdy construction to withstand any ordinary use. They should not, however, be mistreated, and special care should be taken to protect the valves and safety plugs. Tanks should be stored in a dry place away from boilers, combustible material or oxygen. The room should be well ventilated. They should stand in an upright position. It is especially necessary to keep rain and snow out of the heads of tanks with dished ends, particularly in cold weather. Regardless of design, tanks should not be stored in the open in winter, for the user will be unable to draw the full acetylene content from a very cold cylinder. If necessary to keep cylinders in the open, they should be brought into a room at normal shop temperature several hours before using in order to bring the contents up to normal temperature.

If the smell of escaping acetylene indicates that there is a leak in the valve or the safety plugs, the leak should be located by applying soapy water. Never use a match. If the leak is in the valve, close it and tighten the gland nut. If this does not stop the leak, or if the leak is found to be in one of the safety-plugs, put the tank out-of-doors and away from any combustible material, open the valve slightly and allow the acetylene to waste away. The tank should then be plainly tagged "Defective" and returned to the manufacturer.

Acetylene tanks should be handled carefully to prevent denting them. They should not be dropped or used as rollers or supports. They should be kept away from preheating fires and when used for cutting, should be placed where slag or sparks will not fall on the cylinder, the valve, or hose.

All cylinders should be used in the order of their receipt from the manufacturer and should be promptly returned when empty. It is especially important that the valves of empty cylinders be closed when returned to the service station or stored in closed rooms. Acetylene will escape from open valves and sufficient gas will accumulate in a box car or closed room to cause an explosion if a flame is introduced.

CHAPTER II

CHARACTER OF GASES AND THEIR USES

General

Oxygen and acetylene are the two gases of greatest interest to the welder. A properly proportioned mixture of oxygen and acetylene produces the hottest of all known gas flames. The intense heat of this flame, and the ease with which it can be controlled make it the only satisfactory gas for welding.

In cutting, a high flame temperature is not so important and a number of other gases have been used as substitutes of acetylene. In some industrial plants, the relative cost of acetylene cylinder and other gas cylinder transportation and handling is such that advantages may accrue in favor of these substitutes. Some of these gases are changed to liquids in the tanks because of the high pressure, but when the tank valve is opened they pass out as gases. With the exception of hydrogen, practically all of these fuel gases are mixtures of hydro-carbons, that is chemical compounds containing carbon and hydrogen. They are obtained from two general sources:

(1) *Natural Gas.*—Many natural gas wells produce what is known as "wet gas," that is, the gas contains gasoline vapors. Before sending the gas through pipe lines these vapors are removed. When suitably treated the vapors yield high-grade gasoline and some highly combustible gases. The latter are shipped and compressed in cylinders similar to those used for oxygen.

(2) *Oil Gas.*—When petroleum oils are allowed to drop on heated brickwork in a closed retort, a chemical change known as "cracking" takes place. By choosing suitable grades of oil, gaseous hydrocarbons may be obtained as products or the oil may be broken down so completely that hydrogen is one of the gases in the mixture. Indeed, one commercial gas of this character is said to contain about 85 per cent hydrogen, the balance being light hydrocarbons. Many of the commercial products in both these groups are liquids at the pressures used in the tanks so that some device such as an expansion chamber or vaporizer is necessary in order to make them burn properly in the torch. In addition to these two general groups, one company is marketing a gas which is largely ethylene, obtained from ethyl alcohol.

When burned with oxygen, all these gases, including hydrogen, produce a lower flame temperature than is obtained with oxygen and acetylene. Their use is therefore largely restricted to cutting.

As many of these gases are shipped in steel cylinders similar to those used for oxygen, care must be taken to see that the regulator connections are correctly made.

Oxygen

Although oxygen is one of the most widely distributed chemical elements, there is no natural source of the pure gas. The oxygen in the world is either chemically combined with other elements or diluted with other gases, as follows:

(1) *Rocks and Minerals.*—A study of the composition of the rocks and minerals that form the earth's crust indicates that about 46 per cent of this crust is oxygen. All this oxygen is, however, present in chemical compounds that can not be made to yield oxygen economically.

(2) *Water.*—Water is a chemical compound of oxygen and hydrogen, containing about 89 per cent oxygen by weight. With suitable and safe equipment water can be divided into its two elements and is thus one source of pure oxygen.

(3) *Air.*—Air is essentially a mixture of 20 per cent oxygen and 80 per cent nitrogen, by volume.* As the atmosphere is of the same composition throughout the world, it furnishes an inexhaustible as well as a most convenient source of oxygen. Practically all of the oxygen used for oxy-acetylene welding and cutting is obtained from the air.

Properties of Oxygen

When separated from any of these compounds or mixtures, pure oxygen is found to be an odorless, colorless, tasteless gas. From the knowledge that air is about one-fifth oxygen, these properties are just what might be expected. The same is true of its distinguishing property, the ability to support combustion. Experience has shown that a fire can not be kept burning without a sufficient supply of air and scientific investigators have proved that the oxygen in the air is the active substance that makes the fire burn. In other words, combustion is a chemical reaction between oxygen and some other substance, and is characterized by the presence of a flame. As air is only 20 per cent oxygen, it would be only natural to expect that things would burn more rapidly and intensely in pure oxygen than in air. This supposition is exactly what takes place. A splinter that is merely smoldering in air will burst into brilliant flame when placed in pure oxygen. In addition, many substances will burn in oxygen that do not burn at all in air—steel and iron, for example. Iron does combine with oxygen even at ordinary temperatures in air, forming the familiar rust, which is simply iron oxide. An oxide scale forms quite rapidly on the surface of iron heated to a high temperature in air but the iron never really burns with a flame.

Even in pure oxygen, iron does not begin to burn at ordinary temperature. A spot must first be heated to red heat, before the iron will begin to burn. Once started the combustion continues rapidly with a brilliant white flame.

From this brief discussion, it will be evident that the highest flame temperature will be obtained with any combustible substance when it is burned in pure oxygen. The actual temperature in any given instance will of course depend also upon the combustible material used, the highest flame temperature known being obtained when acetylene is burned with oxygen. That is why this combination of gases is so successful in welding.

The problem of distributing oxygen is made easier by the fact that it is non-flammable and non-explosive. It is simply compressed into steel cylinders, the ultimate pressure being limited only by the strength of the cylinder and not by any property of

*Oxygen, 20.99 per cent; nitrogen, 78.03 per cent; argon, 0.93 per cent; neon, krypton, xenon, helium, etc., 0.05 per cent.

the oxygen itself. For practical reasons 2000 lb. per square inch has been adopted by Federal rules as the charging pressure for oxygen cylinders.

There is one point about oxygen under pressure that must always be kept in mind, and that is its increased chemical activity. This is due to the fact that at 2000 lb. per square inch pressure there is about 140 times as much oxygen present in a given volume as at atmospheric pressure (14.7 lb. per square inch). The activity is so much greater that the high pressure oxygen will combine with oil or grease with explosive violence even at ordinary temperatures. That is the reason for the repeated warnings to "Use No. Oil" on oxygen cylinder valves, regulators or lines carrying oxygen under pressure. Oxygen is rated at 12.08 cubic feet per pound, atmospheric pressure, and 70 deg. F.

Acetylene

Acetylene, a colorless, combustible gas having a peculiar sweetish odor, is made by bringing calcium carbide into contact with water. The calcium carbide, a gray stone-like substance made by fusing lime and coke in an electric furnace, reacts with the water to form acetylene, which passes off as a gas, and slaked lime, which settles to the bottom of the acetylene generator as a white sludge.

Acetylene burns in air with a very smoky flame unless a special type of burner is used, when the familiar brilliant white light is obtained. If acetylene and oxygen are mixed in suitable proportions, the mixture burns with an intensely hot, blue, non-luminous flame, the temperature of which is higher than that of any other known gas flame.

Acetylene forms violently explosive mixtures with air or oxygen. The explosive range with air is from 3 per cent acetylene and 97 per cent air to 82 per cent acetylene and 18 per cent air. Accordingly, *great care must always be used to prevent the formation of such explosive mixtures.* Never attempt to locate an acetylene leak with a match or open flame. Use soapy water instead; bubbles will appear at the leak.

Acetylene is a highly endothermic compound. This sounds formidable but it means simply that acetylene would give off a large amount of heat if, for any reason, it should break up into its elements, carbon and hydrogen. Under certain conditions, if acetylene is under a pressure of more than 15 lb. per sq. in., the gas may break up or decompose suddenly, without warning and even without apparent reason. Because of this characteristic, the generation, storage or use of acetylene at pressures above 15-lb. is absolutely forbidden.

As it would be uneconomical to distribute acetylene in cylinders at only 15-lb. pressure, development of the oxy-acetylene process depended upon finding a safe method for getting more acetylene into the cylinders. The solution of the problem was a combination of two suggestions made by scientific investigators. One was

based on the well-known principle of the miner's safety lamp, that an explosion wave will not travel through very fine tubes or openings. The other made use of the discovery that acetone, a liquid chemical, would dissolve about 25 times its own volume of acetylene at atmospheric pressure and that the amount absorbed increased directly with the pressure. That is, at 10 atmospheres (147 lb. per sq. in.), 1 volume of acetone will dissolve about 250 volumes of acetylene. It was also found that dissolving acetylene in acetone practically eliminates the dangerous characteristics of sudden decomposition even when the acetone-acetylene solution is at pressures much higher than 15 lb. per sq. in.

Cylinders for acetylene combine both these methods. The interior of the cylinder is completely filled with a very porous or spongy material which in turn is saturated or soaked with acetone. In properly constructed cylinders of this type, dissolved acetylene may be kept at 250-lb. per sq. in. with perfect safety. Details of acetylene cylinder construction have already been discussed.

Fuel Gases Other Than Acetylene

As already noted, various combustible gases have been used instead of acetylene in cutting. Those distributed commercially include hydrogen, carbo-hydrogen, calorene, pyrogen and butane.

(1) *Hydrogen.*—On page 30 it is mentioned that hydrogen is a product in the manufacture of oxygen by the electrolytic process. The hydrogen is compressed at 1,800 lb. in cylinders resembling those used for oxygen. The oxy-hyrogen flame is not as hot as the oxy-acetylene so that it is unsatisfactory for welding metals like steel. It is used quite extensively, however, in "lead burning" (as it is called, although it is really welding) because the low melting point of lead makes an extremely hot flame unnecessary.

(2) *Carbo-Hydrogen.*—This is a mixture of hydrogen and hydrocarbon gases obtained by heating certain petroleum oils under such conditions that they break down or "crack" into simpler chemical compounds. It is sold in 200 cu. ft. tanks, the pressure being 1,800 lb. per sq. in. It is used for cutting but seldom for welding as the flame temperature is too low.

(3) *Calorene.*—Calorene is obtained from ethyl alcohol by a chemical treatment that gives a gas mixture consisting of ethylene (C_2H_4). This is a hydrocarbon that resembles acetylene in some ways, but does not give as high a flame temperature when burned with oxygen. Its use is, therefore, restricted to cutting and lead burning.

(4) *Pyrogen.*—This is a very combustible gas product obtained during the process of recovering gasoline from natural gas. It is also used for cutting.

(5) *Butane.*—Butane is also obtained as a byproduct in natural gas plants. The comparatively low flame temperature limits its use to cutting.

MANUFACTURE OF OXYGEN

Construction and Operation of Electrolytic Cells and Liquid Air Apparatus

Oxygen is made commercially by two different processes, electrolysis of water, and fractional distillation of liquid air. The product is referred to as "electrolytic" oxygen or "liquid air," depending on the method of manufacture. Formerly, oxygen production by the electrolytic process was much more common than at the present time; now by far the greater proportion is made by the liquid air process.

The electrolytic process is being abandoned since the cost of the gases so produced is greater than the cost of oxygen produced by the liquid air process. However, the electrolytic process has advantages in remote regions far removed from the commercial sources of gas supply. Plants having hydro-electric power can sometimes produce oxygen and hydrogen economically because of freight charges.

In the electrolytic process water, which is a chemical combination of oxygen and hydrogen, is broken down or divided into these two separate gases by passing an electric current through it.

This "breaking down" process is accomplished in small units, called "cells," which are grouped together in banks of twelve or more. Each cell has a positive pole, called the anode and a negative pole called the cathode. These poles are immersed in the water in the cell. Since pure water is a poor conductor of electricity, sodium hydroxide (caustic soda) is dissolved in the water so that the current will flow readily.

When an electric current is passed through the cell *oxygen collects at the positive or anode pole and hydrogen at the negative or cathode pole.* These gases are then piped off separately and compressed into separate cylinders. Hydrogen is used commercially for hardening fats in packing plants, in making soap, and sometimes in cutting steel.

The liquid air process employs entirely different principles. The atmosphere is composed of air consisting of a mechanical mixture (not a chemical compound) of oxygen and nitrogen with a negligible quantity of other gases. The proportions are approximately 21 per cent oxygen and 78 per cent nitrogen and 1 per cent argon and other gases.

Oxygen production by this method is quite an elaborate process. The air is first purified by removing dust, soot, and other foreign particles together with some of the gaseous impurities and is then dried. The pure air by successive stages of compression and cooling is then reduced to a liquid which looks much like water. Liquid air is very cold and has a temperature of about 317 deg. below zero Farenheit.

Liquid air is, of course, mostly liquid oxygen and liquid nitrogen. These two gases liquify at slightly different temperatures,

and therefore return to the form of gas at different temperatures. Since oxygen liquifies at a lower temperature it is possible, in accurately controlled equipment, to allow the nitrogen to escape as a gas while still maintaining the oxygen in the liquid form. When allowed to warm up to ordinary atmospheric temperatures liquid oxygen becomes gaseous oxygen, which is then drawn off into a gas holder and is later compressed into oxygen cylinders.

Oxygen of satisfactory commercial purity is produced by both of these processes. When oxygen is obtained from a reliable manufacturer there is little choice, if any, as to the methods of production. The impurity contained in electrolytic oxygen is principally hydrogen, while in liquid air oxygen it is mainly argon. It has been amply demonstrated, however, that this difference has no appreciable effect upon the efficiency of oxygen for welding or cutting purposes, if the oxygen content is the same.

CHAPTER III.

MATERIALS AND APPARATUS

Characteristics of Rods for Welding Different Metals

In considering the use of any metal for welding rods, the first question likely to be asked is "What is its chemical composition—what is it made of?" The answer to this question is of secondary importance. The two important factors, which determine what metal shall be used for a given purpose are: "Will it perform the service required and what is the least expensive material that may be used?" Since the gas welding torch has proved useful for welding practically every metal and alloy, a description of welding rods necessarily covers a very wide range. In choosing a welding rod, the same principles are applied as in selecting other materials. *As a general rule, the welding rod should have practically the same composition as the material to be welded.* For example, low carbon steel is welded with low carbon steel welding rods. Unfortunately there are two kinds of low carbon steel welding rods, i.e., good and bad, and they are usually of practically the same chemical composition. Certain metal compositions while entirely satisfactory for fencing or for baling wire are entirely unsuited for welding rods. This fact is due to the poor quality of material, although a test shows the same chemical composition as good welding rods. The reason these rods are not satisfactory for welding purposes is due to gases and dirt that are included in the steel during the process of manufacture. In other words, satisfactory oxy-acetylene welding rods must be manufactured especially for this use—welding purposes. The dirt that is contained in impure rods requires extra time and expense on the part of the welder to float it out of the weld. The gases that are contained in poor rods cause bubbles in the melted metal and porosity in the finished weld.

For these reasons, it is essential to procure welding rods of

known dependable quality. The methods by which welders ordinarily test welding rods are first to watch the action of the metal from the rods as it is melted into the weld. Another test for quality is to hold the flame directly at the end of the rod so that it melts and small drops of metal fall off. As the metal melts, any foreign matter can usually be noticed in the usual type of low carbon steel rods. The impurities appear momentarily as tiny white specks. Still another test that is frequently applied to welding rods is to move the flame slowly along the top surface of a welding rod lying in a horizontal position. The rate of movement should be such as to melt slightly more than one-half way through the rod. As the metal solidifies, good quality rods will be smooth and regular in appearance while the metal from "gassy" rods, when cold will contain numerous spongy, volcano-like irregularities. These three simple tests can serve as a basis for the testing of practically all welding rods. In general, the metal should melt quietly and unite readily with the base metal so that the completed weld will be of smooth appearance and free from blowholes or other harmful defects.

It is necessary to use a certain amount of care to employ the correct size welding rod for a given job. If a desirable weld is to be obtained, it is necessary that the edges to be joined and the metal of the welding rod shall both be melted at the same time so that the molten metals from the three pieces will flow together of their own accord and unite in a common mass. Under these conditions the impurities will float to the surface to form a slag and "laps" or "cold shuts" and other faults will not be retained in the weld. Since it is necessary to have the weld metal edges and the rod molten at the same instant, it will be necessary to carry a larger pool of molten metal than is economical if too large a welding rod is used, and this will not only increase the expense of the operation but will also detract from the appearance of the finished weld. If the welding rod used is too small, the tendency will be to overheat the weld. The welding rod, when placed in the melted metal, tends to absorb heat from this metal and thus the rod is heated sufficiently to melt it off gradually at the end and at the same time the heat taken up by the rod prevents overheating of the melted metal. There is, therefore, a definite relation between the size of the rod, the size of the flame, and the thickness of the material that should be maintained.

When a rod is nearly used up it is customary among welders to fuse the short end to a new length and by this means avoid wasting a considerable quantity of welding rod material.

A considerable percentage of all the welding that is done is limited to low carbon steel and the rod generally used for this work is also made of low carbon steel. According to the specifications of the American Welding Society, it should contain less than 0.06 per cent carbon and less than 0.15 per cent manganese. There are various well-known brands of this very low carbon steel which

may be distinguished by the ease with which the rod may be bent and its lack of springiness. During welding this metal flows as a very clear liquid and usually a large number of tiny sparks are thrown off during the melting.

Another type of steel welding rod is one containing slightly more carbon, usually about 0.25 per cent. As a general rule, the welding quality of this rod is not much different from that of the low carbon rod and experience has shown that for the two types of rods the better quality weld is obtained with pure iron rod.

Nickel steel rods are favored by some welders. This material, during welding, has less tendency to sparking and usually there is a very slight amount of slag covering the melted metal. Rods of nickel steel composition have produced welds of exceptional quality, but in general more skill in welding is required for success with these rods than with the plain carbon steels. Certain special welding rod compositions have been developed by the use of which welds of greater strength are obtained than will be given by the usual rods. Satisfactory results may be obtained with any of the steel rods already referred to when welding sheet metal or plates such as are used for tanks, fire boxes or steel castings, in fact any metal except high carbon steel. Alloy rods are available for welding where a hardness of the weld metal for resistance to wear is required or where heat treatment, as for alloy steels, is necessary.

The repair of gray cast iron is probably of second importance in the application of gas welding. For the welding of this metal cast iron rods of special composition are required. Usually the cooling of the weld is more rapid than when the casting was originally made and a special composition of welding rod is necessary to avoid the formation of hard spots in the weld. It should be remembered that wrong welding-rod-composition is not the only cause of hard spots in welds. These rods must also be free from sand or other dirt since the blowholes that are sometimes included in cast iron welds are always caused by dirt in the weld metal. Gray iron welding rods can be recognized by fracturing the metal. The fracture should be gray and not of a bright crystalline appearance.

A great deal of cast iron repair and also production welding, particularly in the joining of pipes, is done with rods of the Tobin or Manganese bronze type. Some manufacturers make rods of the same quality as the two just mentioned under their own trade names. The essential features are that the rods "tin" the cast iron surface without difficulty and that the joint formed shall be free from porosity and of high strength. These rods may be tested by passing the flame along their surfaces at a rate to melt part way through. When the melted metal solidifies, it should be smooth and free from porosity. These same bronze welding rods are generally employed for the welding of brass and bronze and sometimes for welding copper.

For the welding of pure aluminum sheets, drawn pure aluminum welding rods are required. A rather wide variety of aluminum castings are being used and usually a rod of the same composition as the castings is most suitable for the welding. A pure aluminum rod is very soft and extremely ductile while most of the aluminum alloys are stiffer and more brittle than the pure metal.

Another instance of the necessity for intelligent choice of welding rods is in copper welding. A weld made from ordinary copper wire will be filled with blowholes and extremely low in strength. Welding rods of suitable composition contain ingredients which prevent the formation of the gases which produce sponginess in the weld.

In general, the qualifications required of a welding rod are that it be of a composition similar to the metal being welded and that it be free from defects which tend to lower the quality of the weld.

Construction and Operation of Acetylene Generators

An acetylene generator is a machine or device for bringing calcium carbide into contact with water and for collecting and storing the acetylene gas resulting from the chemical action. The generators are of two general types—those in which the water drops upon the carbide, and those in which the carbide drops into the water. The former type is commonly used in small generators, such as miners' lamps, bicycle lamps, etc., while all large generators, such as are used for supplying gas for oxy-acetylene welding and cutting are of the latter type. This book is concerned only with the carbide-to-water type herein. One gallon of water is used for each pound of carbide. This amount is necessary to keep the temperature down because when acetylene is generated heat is produced also. Small amounts of carbide are machine-fed, as needed, into a large volume of water in a tank just below the carbide hopper or storage container. The water absorbs the heat so that the temperature cannot rise above the boiling point. If the temperature is permitted to rise above a certain point, under certain conditions of pressure, the acetylene goes through a process that chemists call polymerization, that is, it breaks down into other gases that are very much less efficient from a welding standpoint. Acetylene, being the nearest approach to gaseous carbon, is the best known fuel gas. Each pound of carbide produces about 4½ cu. ft. of acetylene.

Calcium carbide is supplied to the trade in air-tight metal drums. When exposed to air it slakes the same as quicklime, and in slaking gives off acetylene gas. Drums in good condition are not a source of fire hazard but rough handling received in transportation is likely to loosen the seams of some drums, thus exposing the contents to the action of the air.

For this reason calcium carbide should be stored in rooms separate and apart from the acetylene generator and where no open

fires or lights are employed. A carbide storage room should be ventilated through pipes communicating to the outer air, well above the building roof and any closely adjacent stacks of furnaces and boilers.

Welding generators, like torches, are of the pressure and low-pressure types. Pressure generators produce acetylene at from 5 to 15 lb. pressure. Generating or using free acetylene at more than 15 lb. pressure is not permitted by the National Board of Fire Underwriters, because of the great danger involved. The feeding of the carbide into the water, that is, the generation in the pressure type of generator, is started and stopped by the pressure of the acetylene itself in the generating chamber. The feeding-device control is usually some form of diaphragm mechanism, such as the regulator described in a preceding section. As generation goes on the gas pressure builds up in the generator, exerts a force against the regulator diaphragm which moves levers or arms that close the valve and stop the carbide from feeding into the water. This operation stops further gas generation until a part of the acetylene gas is consumed by the torches and the gas pressure is lowered. When this takes place the regulator reverses its movement. The operation of feeding carbide into the water begins again. These two processes continue to operate according to the needs of the welder and ends when the carbide is all consumed.

In the low-pressure-type generator, control of the feed is accomplished through the volume of the gas instead of through the pressure. The acetylene is generated and stored in a gasholder under less than 1 lb. per square inch pressure from which fact the generator derives its name. The bell or floating part of the gasholder rises or falls, depending on the gas in it and by means of short chains stops or starts a clock motor of simple gears, which in turn shuts off or starts the feeding of carbide into the water and thus controls the generation of gas.

To the inexperienced it may appear that the design and construction of either of these two types of generators is a relatively simple matter, but this is not the case. Numerous problems and troubles arise from the beginning. In the first place, the operations of the parts must be very positive in their action, the generator must both stop and start at just the right moment, otherwise its operation will not be automatic. At the same time there must be no chance of too much carbide being dropped into the water at a time, which would cause too much generation of gas. If, for any reason the entire charge of carbide should fall into the water, a serious accident would probably result. Many manufacturers market a portable generator. These types should always be provided with some device for locking the feed so as to avoid any chance of carbide dropping into the water or of water splashing on the carbide when the generator is moved from place to place. Every generator should be fitted with a safety release or pop valve to relieve the pressure in case any of the parts of the generator

failed to work properly. Acetylene generators should also be fitted with a hydraulic back-pressure valve or some such device to stop any flashback. Although the chances of a flashback returning as far as the generator are rather small, still the chance is always present and proper protection should be made to prevent such an occurrence. In case the torch tip becomes stopped up the back-pressure valve will also prevent any return of oxygen through the acetylene hose into the generator, which might cause an explosive mixture. All of these various safety precautions are fully covered by rules and regulations of the National Board of Fire Underwriters, and every user of an acetylene generator should know that his machine meets all of the requirements. It is almost needless to state that an open flame or fire should never be brought near an acetylene generator and that the operator should never look for a gas leak with a match or an open light, since acetylene gas when mixed with air is highly explosive.

Since a generator contains water, some provision against freezing should be made in cold weather. Some manufacturers of oxy-acetylene equipment supply various anti-freeze solutions. Unfortunately, most of these solutions are unsatisfactory. Some of them evaporate, others have a corrosive effect on the metal, while still others, especially those of an oily character, tend to gum up the moving parts and thus hinder free movement of the operating parts. The best and safest way to prevent freezing is to erect the generator in a specially built generator house that is steam heated. In case the generator or any part of the acetylene system should freeze the operator should not attempt to thaw it out with anything other than hot water. After it has been thawed out he should test the generator thoroughly to make certain no damage has been done to the parts through the freezing of the water.

As a general rule, acetylene generators should be charged by daylight only. Where night charging is necessary an electric light protected by gas-tight globes should be used. A fundamental rule that should never be broken is to avoid the use of a metal rod when charging the carbide hopper. Sparks are easily produced with a metal rod that may ignite the acetylene rising from the generator.

Naturally, the details of charging and operating a generator vary with the different makes. The manufacturer furnishes very detailed rules, however, often in the form of a card or chart that should be posted on the walls or door of the generator house and which everyone who has access to the generator house should be required to know and to observe when working with or around the generator.

CHAPTER IV.

MAKING AND TESTING THE WELD

Testing the Finished Weld

It is obviously necessary to destroy any structure if it is desired to know its ultimate strength. Of course, it is impossible to do

this in each case or instance. It has, therefore, become sound engineering practice to test to destruction one or more samples that are like the completed structure, and to use the results obtained as a basis for design, on the assumption that if other samples are made in a similar way they will be of a strength sufficiently close for all practical purposes to the one destroyed.

It has been found by experience that the designer must use what he calls a "Factor of Safety" to allow for irregularities of various kinds in the construction, such as non-uniformity of material, im-

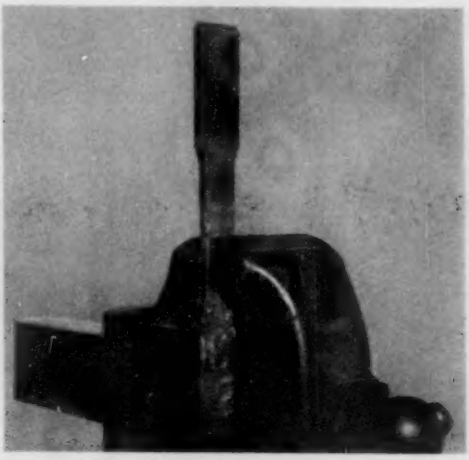


Fig. 12. Test welds set up in vise for bending.

perfections in workmanship and the impossibility of determining the exact stress to which the piece is subjected in service. For example, the ultimate strength of a steel plate may be at one end 60,000 lb. per square inch, while at the other end it may be 70,000 lb. or more, as this is a practical condition that can not be overcome if we wish to keep within reasonable manufacturing cost. With regard to workmanship, it is not possible to secure exact uniformity and the highest quality in every piece that is made, no matter what manufacturing processes are considered. A good illustration of unknown service stresses are those in the case of railroad locomotives and cars. It is evidently impossible to decide beforehand on the exact stresses produced in the various parts of such equipment running at high speeds over tracks that are more or less rough. In the end, experience shows when the part is too weak, and the difficulty is overcome by increasing the strength of the part in some suitable way, either by making it heavier or by using materials of superior quality.

In no case, however, is it possible to utilize the full capacity of the material in the structure in strength calculations. Evidently if the material was stressed this much, it would break, so it is cus-

tomary to load the structure to a point less than this amount, quite frequently using a factor of safety of 5.

It is possible to devise various methods of test to suit the various conditions in service. For instance, a chain is designed to work in tension only, that is, to support a load. Therefore, the only test that is fair to apply to a chain is a tension test. There are very few structures, however, that are as simple in the stresses which they undergo as is a chain. Another comparatively simple case is a tank or pipe subjected to internal pressure. Even in such

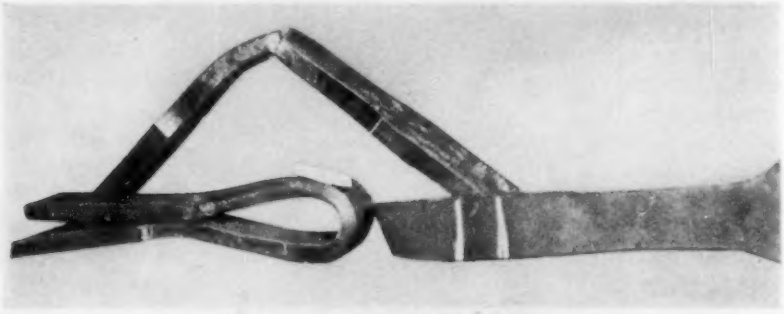


Fig 13. Results of bending test. Upper piece broke in weld; this was caused by poor welding practices. Piece in lower left was bent through weld 180 degrees without showing signs of weakness. The piece in the lower right was tested to destruction in an Olsen testing machine. It will be noticed that the break is well outside of the weld which is indicated by two vertical chalk marks

cases as these there may be other stresses, as from shock due to a suddenly applied load in the case of a chain, or to an explosion inside the pipe or tank. More complicated structures, such as roof trusses require consideration in the design of loading caused by wind, the weight of snow and other irregular loads and many tests have been made to find the effect of these and other loads on all kinds of structures. One common form of test in cases where severe shock is encountered is that used in the case of railroad car axles, commonly called the drop test. In this, a weight is allowed to fall from varying heights on a properly supported axle and the amount of permanent deflection under definite conditions of application of the weight are taken as a measure of the resistance of the axle.

It is, therefore, evident that the testing of any structure, including those made by welding, should be done in a way that will show its resistance to stresses that are known to exist in service. In the case of welded pieces, suggested standard tests of the ultimate strength in tension, bending, compression, shock, alternating stress, torsion and various other ways are outlined in Bulletin No. 1 of the American Welding Society. Such tests can be made on small specimens.

In many cases, and this is as true of welded pieces as of those

not welded, the question of strength does not enter seriously. It may only be desirable to have a smooth finish and the weld would, under such conditions, only need to be free from porosity or other imperfections, and to have a sufficient amount of metal added to allow for proper grinding or other machining. The testing of such a weld would be by visual inspection and this can be done rapidly. In other cases, for instance that of an open tank, the appearance of the weld has little to do with the results, but it must be tight. This test is easily made by filling the vessel with liquid and making a visual inspection for leaks.

Sometimes it is necessary to match the color of the weld with that of the pieces being welded. This is particularly true of brasses and bronzes. In such cases the problem is more compli-

Fig. 14. Welded specimens bent and hammered flat. On each of these the welded section is directly at the top of the bend. Notice that there is no sign of failure

cated, because while the matching may be perfect after the weld is smoothed down, it may discolor in service to a different extent from the base metal. Some ingenuity and research may be needed to produce an alloy that will meet the requirements and at the same time have good welding qualities.

Resistance to corrosion is frequently different in the weld metal to what it is in the base metal. This is an exceedingly complicated matter and usually the best results can only be obtained by service tests, although much may be learned by subjecting the welded pieces to short time tests under control conditions in the laboratory.

The test that is of the most value in the case of welds is that in tension, by which the ultimate strength, that is, the breaking load per square inch of base metal, the yield point or elastic limit, which are to all practical intents and purposes the same, although

technically somewhat different, and the percentage of elongation and reduction of area are determined. In ordinary metallic materials, these tests are made on pieces that are practically homogeneous. A welded piece is not homogeneous and the physical properties of the weld metal and of the base metal are never the same. The qualities of the two metals approximate each other more closely in the case of castings than where forgings are welded. For these reasons tensile tests on welded specimens should be properly made, interpreted, and applied.

One of the most important parts of a welder's training is the testing of specimens of his work. This can be done best by pulling welded test pieces in a tensile testing machine, because this method gives actual numerical results, and as the tests can be made at regular intervals, both during the training period and during the welder's actual service as a welder, his improvement can be easily checked and defects, if any, corrected.

If a testing machine is not available satisfactory results can be obtained by clamping the test pieces on an anvil or in a heavy vise and bending them with a sledge. Such a method is far better than none, as it shows up defects and if properly performed gives a rough idea of the weld strength.

Fig. No. 12 shows a test weld clamped in a device for testing. The results of this method of testing are illustrated by Figs. Nos. 13 and 14. Some of these test pieces show fractures caused by defective welds, while others stand up under the test without signs of weakening.

Fig. No. 13 shows that the upper piece broke in the weld, the break being caused by poor welding practice. The test piece shown in the lower left was bent through the weld for a distance of 180 deg. without showing signs of weakening. The test piece at the lower right was tested to the breaking point in an Olsen testing machine. The break occurred well outside of the weld, as indicated by the two vertical chalk marks. Fig. No. 14 shows two specimens bent and hammered flat. In each of these two test welds the welded section is directly at the top of the bend. In the case of both of these specimens there was found to be no indication of failure, thus indicating a good weld.

Manufacturers test all finished products in some way, the test depending on the nature of the product. Chemical analyses, hardness tests, the breaking of a certain number of pieces, testing samples cut from finished pieces, hydrostatic pressure tests and comparative service tests, are a few of the many means employed. The hydrostatic test is the one usually employed in boiler work, and it should always be used after any part of the boiler is welded. Hammering welds with an ordinary hammer is sometimes of value and any properly made weld will stand this test. The hammer should be sufficiently hard to insure a satisfactory test but not hard enough to cause distortion.

Materials and Their Preparation for Welding

One reason why the gas welding torch is so valuable as a tool for joining metals, either in repair work or in production work, is the very large range of different materials to which the process can be applied with success. When the welder is properly equipped with welding apparatus and with proper welding rods, his first concern is to correctly prepare the materials to be welded.

Beveling.—As a rule, an oxy-acetylene weld can be made as strong or stronger than the parts containing the welded joint. Where this is desirable the weld must be of as great or slightly greater cross section than that of the parts to be welded. Since the metals when melted tend to flow, they will readily bridge across a small opening and because it is essential to have the two edges of the weld molten at the same time, beveling of the edges is necessary so that the torch flame may reach the bottom edge of the material. If this beveling is not done, the fused metal from the top of the weld will run over the insufficiently heated surface at the bottom of the weld and stick to its surface without any actual fusion having taken place at that point between the weld metal and the metal of the parts to be welded together. Therefore, except in metals of $\frac{1}{8}$ in. or less in thickness, beveling of the edges to be joined is required, although $\frac{1}{4}$-in. thick steel may be welded without beveling provided the edges are spaced apart and the welding done on both sides. These exceptions to the general rule may be made since the edges of these thinner metals can be brought to the melting point across their entire section and the weld made to penetrate entirely to the bottom of the edges to be joined.

Two methods of beveling are employed. One consists in beveling each edge to be joined to an angle of about 45 deg. so as to form a 90 deg. vee which can then be filled with the weld metal. In a great many welding jobs this is the only type of vee that can be applied, for it is sometimes impossible to apply the flame to both sides of the joint. The so-called double-vee type of weld is beveled on both sides so that the sharp edges of the two pieces to be joined meet near their central plane in which case there are two vees, one on each side, both of which must be filled in with welding metal. In cases where high strength, on account of need for resistance to severe strains, is required, the double-vee weld is preferable. The bottom of the vee is the point of the weld which is most liable to contain defects. In a single-vee weld, this area which may contain defects is at the outside surface and serves as a point at which failure may originate. If any defects are in the central plane of the welded article, the weakening that results is not of much importance and the welding on the second side gives an opportunity to float out any slag or oxides that were left after the finishing of the welding of the first side. Almost without exception a slight reinforcement of a double-vee weld produces a joint which is of greater strength than the original material.

Preheating.—For satisfactory results in welding, practically all castings must be preheated. This is true because castings are low in ductility and any local heating will produce internal strains of sufficient extent to cause cracking of the base metal. The extent of these strains that are set up is dependent upon the differences in temperature that are produced. It is on this account that less preheating is required when iron or steel castings are repaired by brazing than by welding. The temperature employed in brazing is much lower and, therefore, for a given temperature difference,

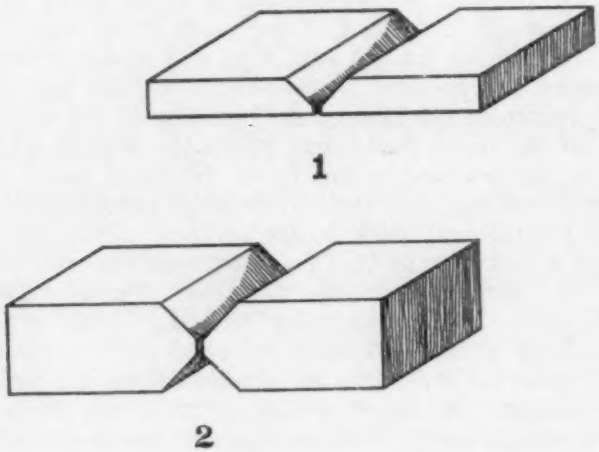


Fig. 15. Pieces prepared for welding. 1—Single vee. 2—Double vee.

a lower preheating temperature is necessary. Correct preheating for welding includes a uniform heating, usually to a dull red color, after which the parts are welded and then reheated to a uniformly red color. This is followed by a slow and uniform cooling. This uniformity of heating and cooling is especially important, because unless suitable control is employed, thin sections will be cooled much more rapidly than the heavier ones and the temperature differences will set up harmful internal strains. A further advantage of preheating is that a certain amount of heat is required to carry on the welding operation. If part of this heat is supplied by burning charcoal or fuel oil, it is done at much less expense than when the welding gases are used.

Similarly, when the casting is preheated, the actual time required for welding is less and a further reduction of expense is thus obtained. In order to produce welds in cast iron or in semi-steel that can be machined slow cooling is also necessary. Where the article being welded is not preheated the relatively cool metal adjacent to the weld will conduct the heat away so rapidly that the metal at the weld is chilled and hard spots very difficult or impossible to machine are produced.

Fluxes.—Except in the welding of wrought iron and steels,

fluxes are usually required for satisfactory results. Impurities on the surface of the metal or impurities contained in the metal find their way into the weld and must be floated out to prevent damage to the weld. Frequently these impurities can be fused only with difficulty. For easy floating to the surface, a liquid slag is required. The combination of a suitable flux with these impurities produces a slag. This easy fusion depends largely on the melting of the material and the fluxes combined with the impurities so as to form a low-melting-point slag. Another function

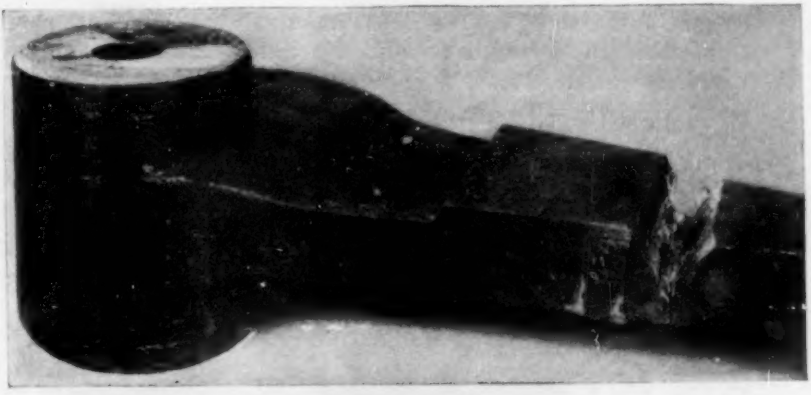


Fig. 16. Method of chamfering cast iron parts

of fluxes is in connection with the brazing of steel or of cast iron where the cleaning of the surface by the flux is required to enable the brazing metal to tin or wet the surface and to adhere properly.

Recognition of Various Materials.—Some of the means by which the materials of the parts to be welded may be recognized are as follows:

Coloring.—It is a well-known fact that aluminum is a grayish white material and that brass ranges from yellow to red in its various compositions. Aluminum alloys when oxidized are usually a darker color than the pure metal and the mixture of copper and zinc in brass metal affects its color as between yellow brass and red brasses.

Appearance of Surface.—A casting can even be recognized by the roughness of the surface while rolled or drawn metals have a smooth surface with very fine lines of grain extending in the direction in which the metal was worked during its manufacture. Forgings can frequently be recognized by the marks produced by the tools and methods of manufacture.

Contour.—The character of the metal can often be determined by the shape of the part. Where irregular or intricate shapes are necessary the casting is often used for making parts that can not be rolled or forged. It is also frequently used because of its

lower cost. The welder, therefore, soon learns to recognize the difference in the kind of metal used by the shape of the part.

Grinding.—The color and nature of the sparks produced by grinding various steel and cast iron metals serves also as a means of distinguishing the one from the other. For example, gray cast iron produces a dull spark which falls without breaking. Steel containing tungsten produces a spark of a decidedly red color. After a few experiments with high carbon steels, the difference in the type of the spark produced can be readily recognized and the kind of metal determined accordingly.

Chisel Cut.—Wrought iron and low carbon steel are very easily cut with a chisel and the chip produced will curl. As the carbon in

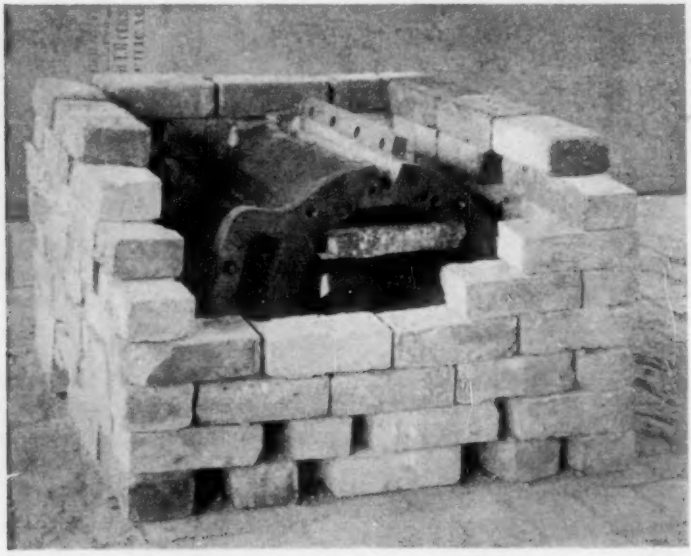


Fig. 17. Fire-brick preheating furnace. Part of wall removed to show casting. Notice draft spaces at bottom

the steel increases, greater difficulty will be met in cutting with the chisel and the chip obtained will be more brittle. When semi-steel and gray cast iron are chiseled, the cutting is not difficult but the chip is very brittle.

Fracture.—Where a fracture of the metal can be observed, considerable information as to its character can usually be obtained. For example, the fracture of wrought iron has a fibrous appearance. Steel is bright and crystalline while cast iron is gray and dull. A malleable iron fracture is usually black in the center and surrounded by a light colored ring at the surface.

Heat Treatment.—As a usual thing heat treatment of welds is not required except for the uniform slow cooling that should follow the welding of a casting. Alloy steels are used largely because of the excellent physical properties that are developed by suitable

heat treatment. Therefore, the variations in temperature between the center of the weld and the weld metal, at sufficient distance to be unaffected by the heat, produce variations in quality because of the uneven heat treatment produced by the welding temperatures. In some cases alloy steels should not be welded, except as a means of temporary repair, until a new part can be secured. For example, in certain cases, if the entire alloy steel article can be given a suitable heat treatment, satisfactory results may be obtained.

High Carbon Steels.—High carbon steels must be given special consideration in welding. Steels containing more than about 0.6 per cent carbon cannot usually be welded successfully as the temperature attained causes burning in the steel. Fortunately the welding of high carbon and alloy steels is not often required. As a general proposition, the lower the carbon content of the steel, the more successful the welding will be.

Welding Regulations

A very complete summary of the rules of various bodies is found in the Welding Encyclopedia. But for surety, the body issuing these instructions should be consulted, as changes are made at intervals. Since rulings of the States and municipalities are often involved, they should be consulted in case of doubt.

As a matter of fairness to the industry, instructions governing any case should never be violated. Boiler welding should not be done on insured boilers unless approved by the company carrying the insurance, and if not insured and State or municipal laws govern, the proper authorities should be consulted. More harm has been done to the cause of welding by injudicious and unauthorized welding than by anything else. No boiler welding should be done except by an expert operator familiar with the work and rules, or by a competent welder acting under expert welding advice. The expert advisor should be well acquainted with boiler construction and operation, as well as with welding. In case of doubt it is much better to turn the job down, as it is then sure that there will be no accident.

Never weld in the shell of a boiler. In general, if the weld is supported by other good construction, no danger will be incurred.

Detail methods of making boiler and firebox welds are given in the Welding Encyclopedia, and much information can be found in the welding and boiler trade journals and the Journal of the American Welding Society.

CHAPTER V

Preliminary Practice Work

Learning to Weld

Hold the torch loosely in the right hand, as indicated in Fig. No. 18, and the welding rod in the other hand, so that the tip of

the incandescent cone almost touches the metal and practice correct torch and welding rod movements. When welding thin metals the flame should be moved slowly across the weld back and forth in a zigzag line and the rod moved in an opposite manner, a shorter distance, while depositing the metal. The flame should not be directed against the welding rod but always on the base metal to produce a pool or puddle, and the rod should be melted by the heat radiated from the flame and puddle. In some cases the rod is given a circular stirring motion and the flame also is operated in a semi-circular path, especially when welding the thicker sections.

Thin metal of a thickness up to 3/16 in. may be welded without beveling the edges. The edges of parts thicker than 3/16 or 1/4 in. should be chamfered or beveled so that when placed edge to edge a groove is formed having an included angle of 60 to 90 degs. The welder should fill this groove with weld metal fusing it thoroughly with the base metal. Great care must be taken to

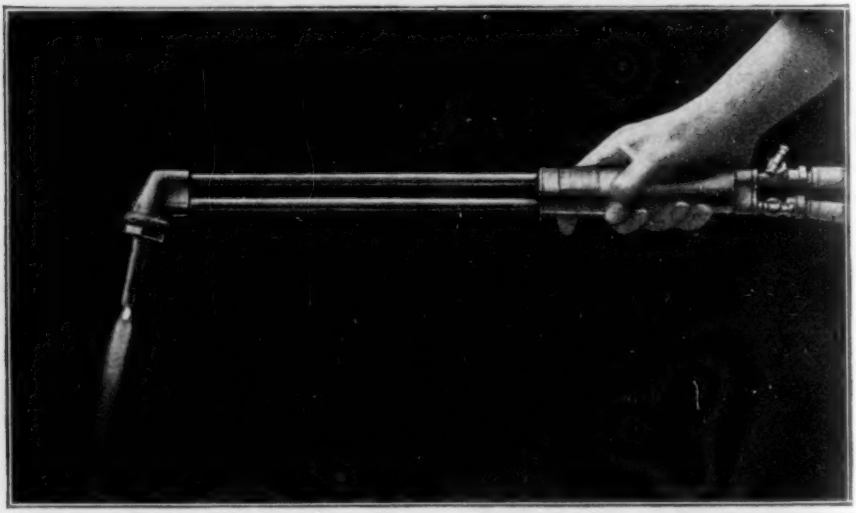


Fig. 18. Correct way to hold torch

break down the edges and obtain thorough penetration. This condition can be obtained only by making the heat of the puddle fuse the welding rod. If the welding rod is melted by the direct flame of the torch insufficient fusion of the base metal will be produced and an adhered weld only will be made.

The operator should practice on thin steel plates first, starting with 1/8 in. plates, and using 1/16 in. welding rod.

After making a practice or test weld break it apart and note the defects. Repeat the weld until able to make a sound weld. After making satisfactory welds in 1/8 in. steel, try 1/4 in. steel and repeat as before until good work can be done. Personal instruction and

criticism from an experienced welder should be sought by the learner.

The following type jobs for preliminary practice have been analyzed so as to give a job specification, a job objective, the auxiliary information, and the science and mathematics which should

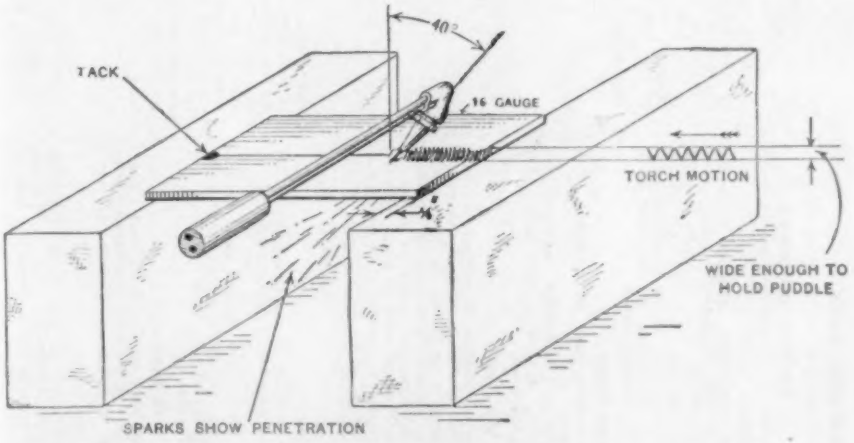


Fig. 19. Manipulation of torch when welding thin sheet steel plates

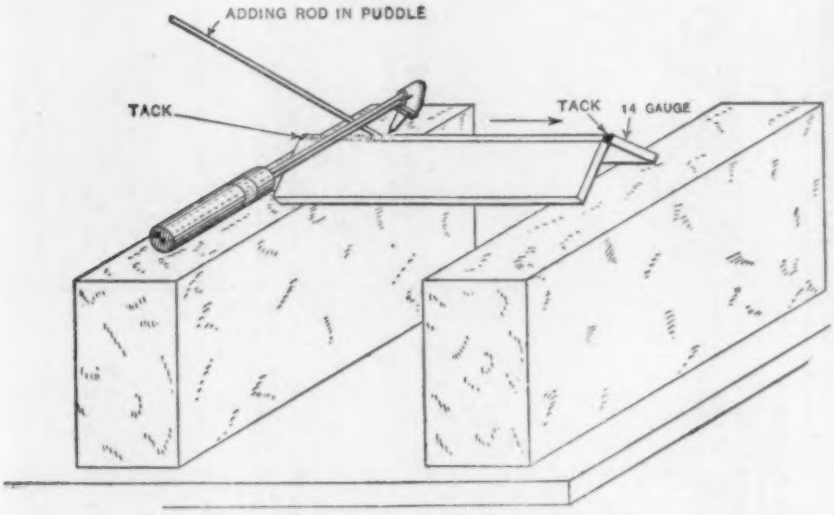


Fig. 20. Making a corner weld in thin steel

be attained and mastered by the learner as he progresses in his welding. As many of the type jobs should be given as necessary to accomplish the training objective for that particular checking level. As soon as possible the learner should be placed on practical work.

ANALYSIS OF PRELIMINARY PRACTICE WORK

Checking Level	Job Specification	Objective	Auxiliary Information	Trade Science Trade Mathematics
1.	**Type Job, No. 1.** Producing and adjusting of torch flame previous to using torch.	To properly adjust torch flame for welding, to realize the importance of care in using the flame and equipment, and to obtain some knowledge of the nature of the gases used.	**Stock:** No recognition of stock is needed at this beginning period. One should be able, however, to recognize the gases used (1) by the appearance of the containers, (2) by their odor, (3) by their burning characteristics. **Trade Terms:** Materials, such as acetylene, oxygen. Tools and equipment, such as torch, tips, regulators, hose, tanks, and containers. **Safety First:** Use of goggles to protect the eyes and gloves to protect the hands, caution so as not to burn others or oneself, and care in directing the flame so as not to injure the equipment, such as hose. Student should be cautioned to extinguish the flame by turning off the gas when not in use.	Creation of the most intense flame by the burning of acetylene by the aid of pure oxygen. Acetylene is produced by dropping carbide into pure water. Oxygen is one-fifth of the volume of air and is produced commercially by (1) liquid air, (2) electrolytic process.
2.	**Type Job, No. 2.** Using torch on piece of cast iron to melt the surface.	To melt the surface of cast iron, successfully overcoming all incidental difficulties.	**Stock:** Recognition of cast iron, (1) by the appearance of the surface, (2) by the fracture, (3) by the action under torch flame, and recognition of its working properties, such as (1) easy melting, (2) fluidity. **Care of Equipment:** Avoidance of flashbacks and knowledge of the proper procedure after a flashback has occurred. **Safety First:** Knowledge of the danger resulting from flashbacks, necessity of keeping torch flame inside the field of vision so as not to injure others, loose tools and materials.	Oxy-acetylene flame is approximately two and one-half times as hot as the melting point of cast iron. The conductivity of two metals such as cast iron and copper vary considerably. Formation of oxide and elimination by flux. Cast iron should be cooled slowly to prevent "hard spots."

3.	**Type Job, No. 3.** Adding metal to a flat surface.	To be able to successfully melt the filler rod into the plate.	**Stock:** Welding rod, flux.	All metals must be melted to make a weld.
4.	**Type Job, No. 4.** Building up "bosses" on flat surface.	To be able to build a "boss" an inch in diameter and an inch in height, to possess control over the melted metal in flat welding, and to use the proper amount of flux.	**Stock:** The working properties of metal with or without the use of flux.	
5.	**Type Job, No. 5.** Welding two prepared flat pieces of cast iron not over ⅜ inch thick and 2 inches in length, single V.	To properly weld two prepared, flat, pieces of metal together, using the proper amount of filler.		
6.	**Type Job, No. 6.** Reducing an irregular surface to a definite level.	To produce a level surface free from blowholes and hard spots, to control the metal and prevent it from flowing over unguarded edges. Student should test finished surfaces for imperfections.	**Stock:** Working properties of stock as affected by foreign elements, such as dyes, oils, grease, etc.	**Science—6.** Metal in molten state seeks a level. In welds the molten metal can be maintained out of level by proper handling of the torch.

CHAPTER VI

Welding Cast Iron

Some Practical Problems in Welding Cast Iron

Problem No. 1—Welding Sample Pieces

(1) Prepare the sample pieces with 45 deg. bevels as shown in Fig. No. 21. Place the two beveled edges together. Use the proper size head or tip with the proper gas pressures, and a ¼-in. cast-iron welding rod.

(2) Provide a sufficient quantity of flux, as has been explained on page 43, which is added with the welding rod to prevent oxidation and to help remove impurities. In order to show the purpose of a flux, the first sample should be welded without it.

(3) The welding flame should be properly adjusted and the

Fig. 21. A 45° bevel and the finished weld.

bottom of the vee melted. The flame should then be applied to the sides of the vee, and the metal brought to the point of fusion.

(4) After a puddle of molten metal has been formed the rod should be held with one end in the puddle and the welding flame swung around the rod from one side of the vee to the other. The welding should be carried on in a series of molten puddles.

It will be noted that the metal is covered with a scale or coating that is difficult to remove. The use of the flux as called for in the next problem will aid in removing this scale or coating.

(5) After this preliminary job is completed without the use of flux another sample should be prepared in the same way. On this second job the operations should be carried on in the same manner as before, except that a flux should be used. The application of the flux is made by dipping the hot end of the welding rod into the flux, a small quantity of which will stick to the rod. When the rod is inserted into the weld, this flux will melt off. The flux should be added to the weld whenever scale, sand or dirt appears. Too much flux should not be used, as it will have a bad effect on the weld.

(6) The rod should be added as described and the weld carried on with little puddles of metal. Sand, scale and blowholes should be worked out of the molten metal by means of the flux and the motion of the rod. Whenever a white spot appears in the melted

metal, it is either scale, sand or some other impurity. If it is allowed to remain in the weld, it will form a defect, and, therefore, should be scraped out with the rod and removed from the latter by tapping against the casting or the table edge or otherwise. Dirt left on the rod will be put back in the weld as soon as the rod is applied again.

(7) The welding should be carried on continuously as fast as possible until the job is completed. If it is absolutely necessary to go back over the weld, always add metal from the welding rod. The finished weld should be solid all the way through, and should be sufficiently soft so that it can be machined. A good cast iron welding rod will aid in obtaining a soft weld.

Cast iron welds will be hard if they are not cooled slowly, or annealed. Immediately after the weld has been finished and while it is still at a bright red heat, scrape off the surface to remove the flux, scale and dirt that have been worked out of the metal. If

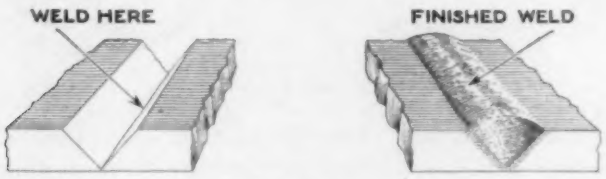


Fig. 22. Welding ¾" cast iron

this is not done the weld will have a very hard skin, notwithstanding the fact that it might be soft underneath. This scraping can be done with a wire brush, the blunt end of a file, or any piece of flat metal.

Problem No. 2—Welding Sample Pieces

(1) Secure two pieces of cast iron ¾ in. thick and prepare them for welding by beveling the edges at 45 deg. The proper welding head, and gas pressure should be determined and ⅜-in. welding rod and the necessary flux provided.

Since the cast iron in this problem is thicker than that in the preceding one, greater care must be used in welding to obtain a solid weld, and in working out dirt and blowholes. The methods of welding and slow cooling are as described in Problem No. 1. The weld should be smooth and soft when finished.

Problem No. 3—Preheating Gray Iron Castings

The crack "A," shown in Fig. No. 23, should be welded first. Before welding the crack should be beveled out in accordance with previous instructions and the wheel, with careful handling, may be locally preheated, within the sections shown by dotted lines, to a dark red heat.

It will be noted that the area for preheating includes a spoke on

each side of the broken part. This procedure should always be followed where a spoke is broken. While the wheel is still at red heat it should be welded. After welding it should be slowly cooled in the preheating fire and protected from drafts with asbestos paper.

Crack "B" should be welded after the casting is cooled from the other weld. The crack should be veed properly, and then the

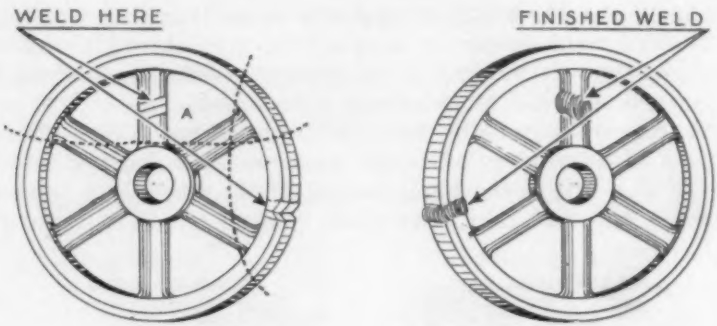


Fig. 23. A cast iron welding job

casting again preheated. The preheating should be brought to a dull red heat and the welding carried on while at this temperature. The wheel should then be allowed to cool in the preheating fire, as was done in the previous case.

When the crack in the rim is located near the center, between two spokes, a preheating fire should be built between the spokes

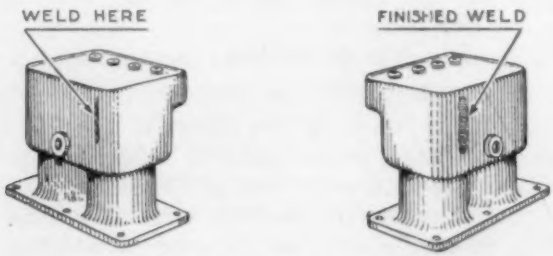


Fig. 24. Repairing a water jacket

and away from the hub. When the crack is near the spoke, as is shown, the preheating fire should include the part of the spoke and part of the rim, but kept away from the hub.

Problem No. 4—Welding Automobile Engine Cylinders

For this problem a block of two cylinders will be considered. The first break to be repaired is in the water jacket, as shown in Fig. No. 24. The second break is on the flange, as shown in Fig. No. 26, and the third is in the water jacket, as shown in Fig. No.

27. The fourth is a crack on the head of the cylinder, extending from a spark plug thimble over the dome to the bore of the cylinder, as shown in Fig. No. 28.

In each of these cases, as is usual in welding cylinder blocks, it is necessary to preheat the cylinder. To preheat the cylinder a furnace is built around it with fire brick. In order to give this furnace draft the bottom row of bricks should be placed about 1 in. apart, as shown in Fig. No. 25. The cylinder should be placed in this furnace with the bore up and the head of the cylinder rest-

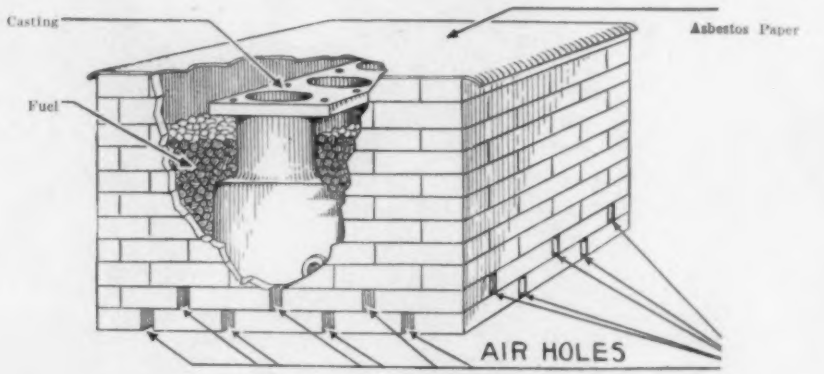


Fig. 25. Method of Preheating

ing on two bricks. The furnace should be so built that there is a 6-in. space between the walls of the furnace and the cylinder. This space should be wide enough to allow turning the cylinder in the fire without knocking down the walls of the furnace. About three shovels of charcoal should be placed around the cylinder at first, and the charcoal lighted by the welding flame. After the charcoal has become thoroughly ignited, and the cylinder has become slightly heated, more charcoal should be added until half the casting is covered. Then a piece of asbestos paper should be placed over the top of the furnace and a few holes punched in it to allow for draft.

In this problem the preheating may be accomplished as just described, or a gas or oil preheating torch, or other means may be employed to bring the casting up to the desired temperature before welding. Whatever the means employed the same general provisions and precautions as given for the brick furnace apply.

The cylinder should be left in the furnace until it is brought up to a dark-red heat, after which the cylinder should be turned so that the part to be welded can easily be reached. The asbestos sheet should then be replaced and a hole cut in it so that the cylinder can be reached by the torch and welding rod. The cylinder should not be taken out of the fire to weld it and the fire should not be permitted to go out during the welding. After welding,

add more charcoal to bring the cylinder to an even heat, and then leave the cylinder in the furnace to cool slowly.

Care must be taken to see that the added metal does not run through the crack and settle in the water jacket, that all dirt and scale is removed, and that no pinholes or blowholes are left in the weld. In order to prevent the bore of the cylinder from scaling it should be given a slight coat of oil before it is placed in the pre-

Fig. 26. Repairing flange of water jacket

Fig. 27. Repairing water jacket

heating furnace, and then a thin coating of flake graphite applied. This application is made by taking the graphite in the hand and throwing it against the oily side of the bore, where the oil will cause it to stick. After the welding is finished, this coating can be cleaned off with a rag or a piece of waste.

The crack shown in Fig. No. 26 can be welded by preheating in the same manner as just described. It is not necessary, however, to preheat the casting to a dark red since in this case the cylinder may be welded at a blue heat.

The crack shown in Fig. No. 27 should be welded in the same manner as the crack shown in Fig. No. 24. The crack shown in Fig. No. 28 should be treated a little differently, because if the crack is on the inside of the water jacket a portion of the outer wall, over the crack, must be removed. The crack is then prepared for welding and placed in a preheating furnace, as described in previous problems, and the welding is carried on in the same manner. When the weld is finished, and while the casting is still hot, the portion removed should be placed back in position in the outer

jacket and welded into place. In order to hold this patch in position while it is being welded, a piece of cast iron rod may be welded to it, this serving as a handle. After the patch has been welded in, the rod can be cut off. The reheating should be carried on as previously described and the casting allowed to cool slowly.

After the cylinder has been welded and has cooled to normal temperature, it should be tested to make sure that the weld is tight. Wherever it is possible, this test should be made with water pressure. If it is impossible to supply water under pressure, the water

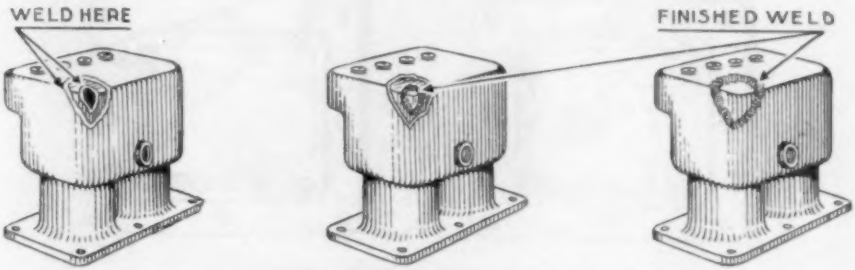


Fig. 28. Repairing crack on inside of water jacket

jacket should be filled with kerosene, which will penetrate a crack or a pinhole faster than water, when not under compression and will, therefore, indicate defects in the weld. In case any defects are found in the weld the metal should be removed at that point and the casting rewelded.

Problem No. 5—Lining Up and Welding a Cast Iron Frame

Broken pieces should be prepared by beveling, and should be laid out so that the holes and surfaces line up exactly, as in the original casting. The pieces should be preheated if necessary and welded together in the same manner as described in previous problems. When the job is completed the weld should be inspected for smoothness, shrinkage cracks and alignment.

Welding the cast iron flange, shown in Fig. 30, should be carried on as in Problem No. 3, the only difference being in the shape of the casting.

Problem No. 7—Welding Heavy Cast Iron Sections

A representative job is a broken punch press frame or shear arm. The size of a typical shear arm is about 6 in. or 8 in. in thickness and about 16 in. across. In preparing a casting of this size for welding it should be beveled from both sides at about a 90 deg. total angle.

Welding from both sides will necessitate turning the casting over when the first part of the weld has been completed. This should be provided for by placing the preheating furnace within reach of a crane or some other mechanical equipment for handling

heavy parts. The casting should be lined up by means of a straight edge. An I-beam can be used for this purpose. A preheating furnace should then be built around the break with loose fire brick allowing sufficient space for the necessary amount of charcoal.

Bring the casting to a bright red heat. Two welders should work on this job; one man to relieve the other at intervals of about 30 min. each. A large welding head should be used, and a long-

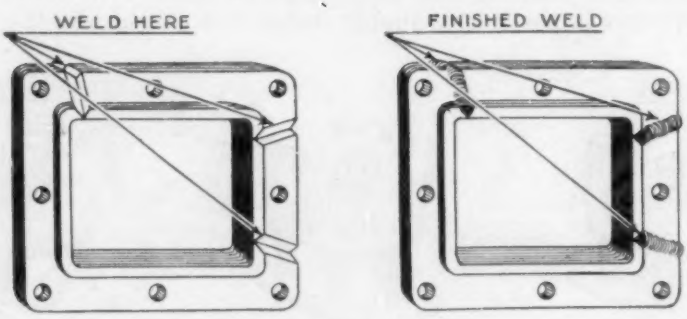


Fig. 29. Repairing broken casting

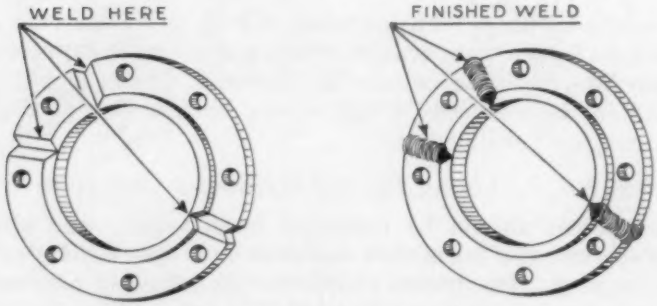


Fig. 30. Welding a cast iron flange

handled torch and $\frac{3}{8}$-in. welding rod will be required. There should be plenty of rods on hand to finish the weld and also plenty of flux. There should also be a supply of asbestos paper and a bucket of water handy. The asbestos paper is used to protect the welders from the heat and to keep the heat in the casting. The water is necessary to cool the torch tip from time to time.

The welding procedure is the same as described in the other cast iron problems. When the torch tip becomes hot, it can be cooled off by dipping it in water. When this is done, the acetylene should be turned off and the oxygen valve adjusted so that just a little is passing through the torch. This prevents the water backing up into the torch. The operators should take turns at the job until the weld is completed from one side. The casting should then be turned over so the uncompleted part of the weld will be within reach of the operator. While the casting is being turned care

should be exercised to prevent chilling by unintentionally exposing the heated casting to drafts. It will be necessary to build up the preheating furnace to keep the entire part being welded at the proper temperature, and in some cases to erect a platform for the operators to work from. The second side should then be welded as was the first.

In a job of this kind it is necessary to reinforce the weld on both sides. This is done at the time of welding. The reinforcing should be about ½ in. in height. It can be added by the torch alone, but in order to save time it may be done by placing one

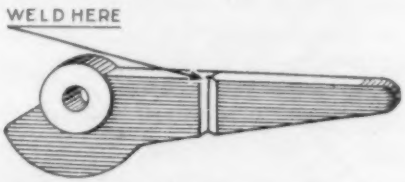


Fig. 31. Welding a heavy casting

Fig. 32. Filling up blow holes

carbon block on each side of the weld for the extent of the reinforcing, which serves as a dam to prevent the metal from flowing out over the casting. After the welding is completed, the position of the casting should be changed to put the welded part well down into the preheating furnace, and charcoal should be added to the fire so as to bring the casting up to an even temperature after which it should be allowed to cool slowly in the preheating furnace.

Problem No. 8—Filling Up Holes

Select the proper size welding tip and welding rod. The piece in which the hole is located should be brought up to a dark-red heat by means of the welding flame applied across the area where the hole is located. If a larger casting than that shown is to be welded a charcoal fire should be used for preheating. Since cast iron will flow easily when melted, the hole should be backed up with a piece of fire brick, asbestos, or steel plate.

The edge of the hole, at one point, should be brought to the melting point by use of the welding flame, and a beveled surface on which to add welding rod formed. This operation should then

be extended all around the hole until it is completely filled; the operation ending in the center and not on the side.

The manipulation of the welding rod and torch is as has been described. Be sure that the bottom edges of the hole are melted and thoroughly welded. This can be observed by turning the casting over and examining the weld. The surface of the finished weld should be cleaned off and the weld allowed to cool slowly.

Problem No. 9—Building Up Lugs and Bosses

Build a lug on the plate used in Problem No. 8, following the same method as employed in all cast iron welding.

Fig. 33. Building up lug

Since machining of the finished weld is an additional operation involving more expense, it is important that the lug be built as near as possible to the shape and size finally required.

Problem No. 10.—Building Up Teeth on Geors or Pinions

The proper welding tip and welding rod should be selected. If the gear is a light one—that is, if the face is not more than 3 in. in width and the rim not more than 1 in. in thickness—the job may possibly be done without preheating. In the case of heavier gears the job should be preheated.

The preheating should be done with a charcoal fire, as in welding the cylinder block. (Problem No. 4).

In doing a job of this kind the greatest care should be taken to

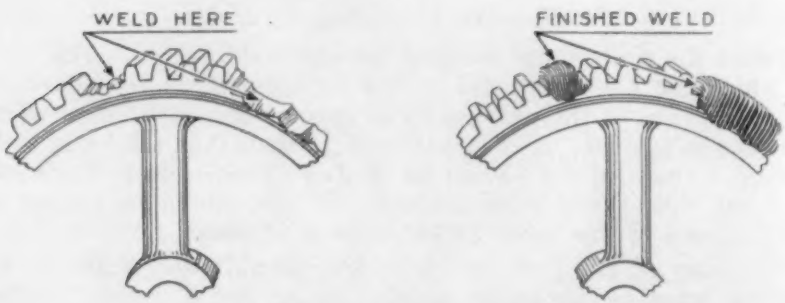


Fig. 34. Building up broken gear teeth

start it properly. The metal on the rim of the gear to which the tooth is to be added must first be melted thoroughly. The welding rod metal is then added. It is necessary to control the metal so that the least amount of machining or finishing is required, and in many cases, the tooth can be built up by using welding carbon blocks that have been shaped out to fit between the good teeth. If these carbon blocks are correctly shaped and properly placed the resulting tooth will require very little finishing or machining.

Care must be taken to see that the tooth is built up fully and that a little metal extends over each end. This extra metal can later be removed with a file. To add the extra metal the torch flame should be held at the side of the tooth; that is, on the edge of the rim, and the direction of the flame should be horizontal. This procedure is necessary to keep the metal from running down on the side.

In order that the weld metal may be machined if necessary and to insure a finished tooth that will not be brittle and crack off when used, the weld must be cooled slowly.

CHAPTER VII

OXY-ACETYLENE CUTTING

The metals that can be cut with the oxy-acetylene cutting torch are all commercial forms of iron, such as steel, wrought iron and cast iron.

Since the cutting action is dependent upon the chemical reaction between the *metal* and *oxygen*, it is desirable that the surface should be cleaned before attempting to cut. Dirt and scale should be scraped off or removed with a stiff wire brush. Layers of paint and other foreign matter slow down the action and waste oxygen.

Cutting Procedure for Steel

Straight Line Cutting.—For practice in cutting, it is best to start with a piece of ½ in. steel plate about 6 in. wide. Rule a chalk line about ½ in. from one edge of the plate and place it so the line just clears the far side of the welding table. Connect a cutting torch to a cylinder of oxygen and one of acetylene, insert the proper size nozzle and adjust pressures for ½ in. metal. Before proceeding further the learner should put on goggles, light the torch, adjust the preheating flames to neutral, and switch off the cutting oxygen.

The cutting torch is now ready for use. Hold the torch as shown in Fig. No. 35 so that the preheating flames just touch the end of the chalk line on the edge of the steel plate. Hold the torch steady until this spot has been raised to a bright red heat, then open the cutting valve and move the torch slowly, but steadily, along the chalk line. If the cut has started properly, a shower of

sparks will fall from the under side of the plate. This indicates that the cut is penetrating entirely through the plate. The movement of the torch should be just fast enough so that the cut continues to penetrate the plate completely.

If the torch is moved too rapidly, the cutting jet will fail to penetrate entirely through the plate and the cutting will stop. Should this happen, immediately close the cutting valve and preheat the point where the cut stopped until it is a bright red. On opening the cutting valve there should be no difficulty in re-starting a cut.

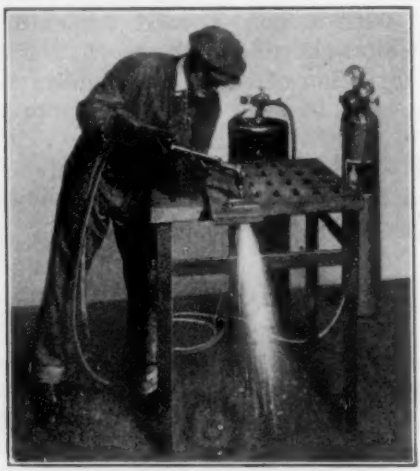


Fig. 35. Position for cutting

If, on the other hand, the torch is not moved rapidly enough, the heat of the preheating flames will tend melt the edges of the cut, producing a very ragged appearance, or at times fusing the metal together again. With a little practice, however, the student will soon be able to make a clean, sharp, narrow cut.

At first the beginner may be surprised to find that although he has apparently cut through the plate the two pieces still hold together. What has happened is simply that some of the slag produced by the cutting action has bridged across and on cooling holds the two pieces of plate together. This slag is quite brittle, and the plates can be easily separated with a blow from a hammer.

Beveling.—Beveling is a common operation with the cutting torch and one that should be mastered by all welders. The operation is performed by holding the torch head at an inclined angle instead of vertically.

For example, place a piece of ½-in. or thicker plate so one edge projects 3 or 4 in. over the side of the welding table. Incline the torch head at an angle of 45 deg. to the top surface, and cut a triangular prism off the edge. After the cut is finished, the piece of plate remaining will have one edge beveled at an angle of 45 deg.

Cutting Holes.—To cut a small hole support a piece of ½-in. steel plate between two fire bricks on top of the welding table. Hold the torch just over the center of the plate until the preheating flames have heated a round spot bright red. Open the cutting valve very gradually, to avoid blowing slag back into the torch tip. It will be found that a small round hole can quickly be pierced right through the plate.

Where a hole of larger size is desired in the plate, the proper procedure is as follows: First, mark with chalk the line that will

Fig. 36

Fig. 36-A

Position of torch in cutting cast iron

form the edge of the hole (which of course may be circular, rectangular or irregular). Then at some point inside of this outlined area pierce a hole with the cutting torch as just described. Start a cut from this point, working toward and then following the line that has been drawn on the plate. In this way the hole will have clean, sharp edges all around.

Truly round holes may be made with the help of a radius bar or a compass, one leg of which is fixed at the center and the other is made by the torch nozzle.

Cutting Cast Iron.—In spite of the fact that steel and cast iron each contain well over 90 per cent iron, the two metals behave quite differently under the cutting torch. In fact, until recent years, it was thought impossible to cut cast iron with the oxy-acetylene torch. With low pressure torches, however, there is no difficulty in cutting cast iron, once the operator has become familiar with its somewhat different action.

Four Points of Difference.—The operator should continually bear in mind these several important differences between the methods for cutting cast iron and those employed for cutting steel: *First*, the preheating flames should be adjusted with an excess of acetylene. *Second*, the nozzle must be held farther away from the metal. *Third*, it is necessary to preheat for a longer period, be-

cause the cast iron must be almost molten before the cut will start. *Fourth*, the nozzle must be oscillated continually across the line of cut.

There are also decided differences in the quality of the various cast irons that cause variations in the ease with which they may be cut. The grade of castings known in the trade as "good grade iron castings" is very much easier to cut than the poorer material used for such parts as grate bars or floor plates.

Procedure for Cutting Good Grade Iron Castings.—(1) Adjust oxygen cutting regular so as to give the correct pressure for the

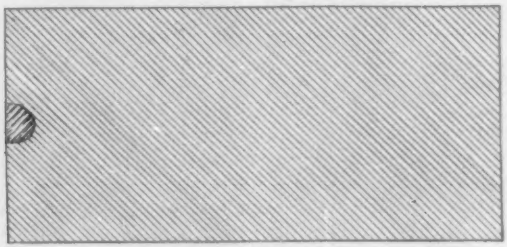


Fig. 37. Starting cut, showing swinging motion

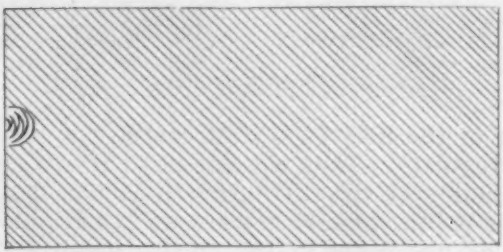


Fig. 38. The molten area

thickness of the cut. This information is furnished by manufacturers of cutting equipment. This adjustment should be made with the cutting valve open. Then close the cutting valve.

(2) Open the oxygen valve slightly and the acetylene valve at the torch fully and light the torch. With the cutting valve open, adjust the heating flames to give the correct excess of acetylene, as noted in the instructions supplied by the manufacturer of the torch. The amount will vary for different makes of torches. The oxygen pressure must be increased with the thickness of the metal to be cut. The exact pressure of oxygen to be used in each case is given by the manufacturer.

(3) Close the oxygen cutting valve. Then begin with a preliminary preheating with the nozzle along the edge to be cut, from top to bottom. That is, preheat what will be the first "bite" of the cutting torch through the entire thickness of the metal. If

this part of the casting is warmed the cut will start quicker and more easily. In general, the warmer the whole mass of iron, the easier it is to cut.

(4) After the preheating is accomplished hold the torch so that the tip points backward at an angle of 75 deg. (that is, back off the edge of the casting to be cut, as shown in Fig. 36).

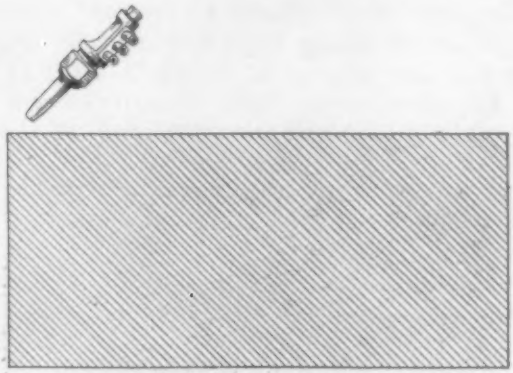


Fig. 39. Showing angle of nozzle at start

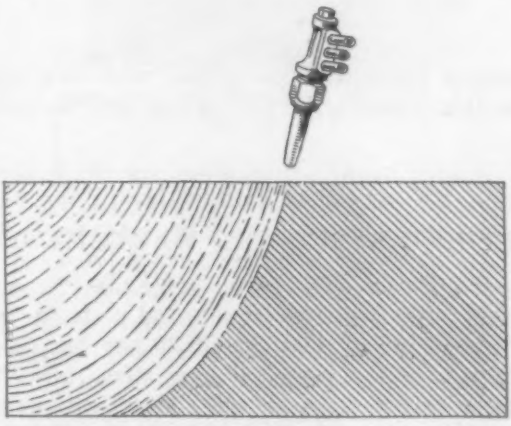


Fig. 40. Showing angle of nozzle as cut progresses

The inner cones of the flame (not the excess cones) should be $\frac{1}{8}$ to $\frac{1}{4}$ in. above the surface, as shown in Fig. 36-a.

To start the cut give the nozzle a swinging motion describing semi-circles across the line of cut, as shown in Fig. 37.

Heat a semi-circular area about $\frac{1}{2}$ to $\frac{3}{4}$ in. in diameter, as shown in Fig. 38, until the metal is actually molten. When the metal begins to "boil" open the cutting valve for an instant to blow off the slag.

(5) Move the tip just off the heated edge, open the cutting

valve *quickly* and then move the torch along the line of cut (with the nozzle now at an angle of 45 deg., as shown in Fig. 39. Use the same swinging motion described in paragraph 4 and keep the metal *hot*.

(6) As the cut progresses, gradually straighten up the torch until it is at an angle of about 75 deg., as shown in Fig. 40. On heavy material the metal will be sufficiently preheated by the cutting reaction and the cut should go forward regularly.

The torch should be swung from side to side, describing semi-circles across the line of cut, as shown in Fig. 41, for the entire length. The diameter of these semi-circles will depend upon the thickness of the metal and the proficiency of the operator.

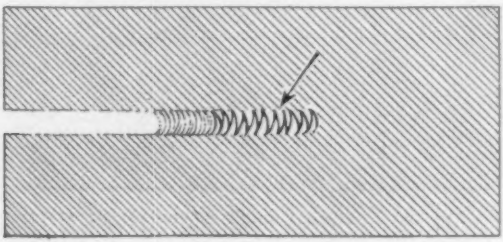


Fig. 41. Lateral motion of torch when cutting cast iron.

As the operator becomes experienced with this work he will be able to reduce the diameter of the swing, and therefore the width of the kerfs.

CHAPTER VIII

WELDING STEEL AND WROUGHT IRON

Nature of Steel Plate.—The term "steel plate" covers steel more than ⅛ in. thick. For best results selected plate for welding should have a low carbon content, less than 0.30 per cent. Steel used for structural shapes, boiler plate, flange steel, pipe steel and the grade commonly referred to as mild steel, all come within this classification. Most "tank" steel is low carbon, but this grade should be watched since sometimes material rather high in carbon and fairly low in quality, is sold as tank steel. The steel should also work well and quietly (without sparking) under the torch flame. This, of course, can be determined only by actual welding tests with a piece taken from each lot of steel.

Selection of Rod.—Thicker steel plate is prepared for welding by beveling the edges that are to be welded together. It is, therefore, necessary to use welding rod in order to replace this metal and build up the weld to the original surface. For average work a low carbon steel rod (often called "Norway Iron") may be used. In any case the welder must remember that "welding rod" is not

just any old iron wire, but material made under strict specification and inspection and designed for that special purpose.

Neutral Flame Used.—For welding steel, the flame should always be neutral. An oxidizing flame will form iron oxide, some of which will remain in the weld and greatly reduce its strength. The welder should form the habit of looking at the flame from time to time to make sure that it is neutral. The position of the welder is shown in Fig. 42.

Torch Technique.—After putting on goggles, light the torch and adjust the flame to neutral position.

Fig. 42. Position of welder when welding steel plate

Melt one end of the vee, holding the torch with the head inclined at an angle of about 60 deg. to the plane of the weld. This is the average welding position. If the head were tilted further the molten metal might be blown ahead of the welding zone; if it were more nearly vertical, the preheating effect of the outer flame would not be thoroughly applied and there would be more danger of melting and blowing a hole through the bottom of the weld. The tip of the inner cone should not quite touch the molten metal.

In plate of this thickness it is clear that the metal from both sides of the vee can not be thoroughly fused unless the torch is moved from side to side across the vee. For this reason it is necessary to develop a swinging motion when welding steel plate. When the end of the vee has begun to melt, move the nozzle from one side of the vee to the other and back again, making sure that the metal on each side is thoroughly fused. At the same time the nozzle must work forward along the line of the weld.

If difficulty is experienced in acquiring the necessary swing, it may be advisable to complete this first weld at the bottom of the vee without attempting to add any welding rod. Merely move the torch gradually along the line of weld, as fast as the metal becomes

well melted, at the same time swinging the flame from side to side, as indicated in Fig. 43.

Use of Welding Rod.—When the torch motion has been mastered set up two more pieces of plate in the same way and repeat the experiment, using a welding rod. The weld should be started just as before; that is, a small spot at one end of the vee should be thoroughly melted, forming a small puddle of molten metal. While this puddle is being formed, the tip of the welding rod should be brought into the outer envelope flame of the torch. In this way the end of the rod is heated; by the time the puddle of molten steel

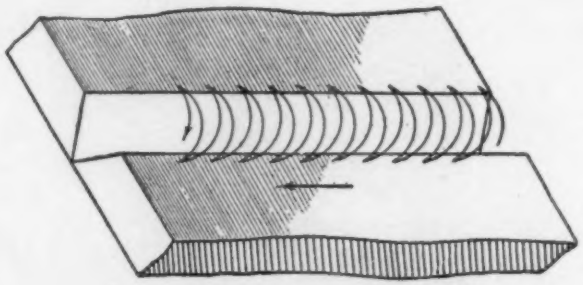


Fig. 43. Swinging motion of torch.

has been formed at the bottom of the vee, the welding rod should be almost to the melting point. Before it actually begins to melt, however, the tip of the rod should be dipped below the surface of the molten puddle. Steel welding rod should always be added in this way. Never hold the tip of the rod above the surface of the molten puddle and allow it to melt drop by drop into the puddle. The reason for this is, of course, that rod melted under the surface of the puddle is completely protected from oxidation.

As the rod melts it should be moved from side to side in the puddle, the motion being just opposite to that of the nozzle. At first it will be found quite difficult to coordinate the motions of each hand. If attention is diverted from the rod to the torch the tip of the rod may be moved out of the molten puddle. When this happens, the rod instantly sticks to the cooler metal on the sides of the vee and it will have to be melted off with the flame before welding can proceed. The beginner will probably find this very annoying, but before long he will be able to control the motion of the rod so the tip is always free and in the molten puddle.

Short Ends of Rod.—According to the individual preference of the welder, the rod may be held straight or, as is more common, bent, as shown in Fig. 42. Hold the rod in the flame until red hot and then bend it at the hot spot by pushing the end against the top of the welding table. When a length of welding rod has been used down to the point where it becomes uncomfortable to hold, a new length can be quickly welded on. To weld on a new

length take the flame away from the weld while the tip of the rod is still under the molten puddle. The metal will cool rapidly and hold the rod in a rigid position. Take a new length of welding rod and, holding it in contact with the old piece, weld the ends together in the torch flame. This operation requires only a few seconds and has the advantage of using up the rod completely.

Reinforcement.—As the weld proceeds, the rod metal should be added until the surface of the joint is built up a little above the edge of the plates. This reinforcement is customary in all welding on steel plate. The small amount of oxide that forms during welding remains on the surface as a scale and can be easily removed when cold. Any impurities that may have existed in the original steel also tend to work to the surface during the welding. In the completed joint they will consequently be located in the reinforcing portion. This can be removed, if desired, by grinding or machining, leaving metal of highest quality and of uniform thickness with the rest of the plate.

The welded joint is completed by gradually advancing the puddle of molten metal until the end of the vee is reached. At this point, in order to finish the work properly, it will be necessary to prevent the molten metal from running over the edge. As the end of the weld is approached, the operator should raise the torch flame slightly and thus chill the molten metal slightly so it will not run over the edge.

CHAPTER IX

WELDING NON-FERROUS METALS

Welding Aluminum

Aluminum, both as cast aluminum and as sheet aluminum, has several properties that make special welding problems. It has a high rate of thermal conductivity and a low fusion point. That is to say it draws heat rapidly away from the welding flame back into the colder metal, and it melts before it gets red hot. On being heated it maintains its form and color without change until the melting point is almost reached, and then suddenly collapses. Aluminum is also very weak when hot, and therefore it is often desirable to support it in some way for welding. Its behavior is so different from that of steel or cast iron that the welder, experienced only in these two metals, will find it necessary to practice considerably before he can handle aluminum successfully.

Aluminum Oxide.—Molten aluminum exposed to the air oxidizes rapidly at relatively low temperatures, the oxide forming a heavy, thick scum over the fluid metal. This oxide has a melting point much higher than aluminum itself; consequently, it does not form a fusible slag on the surface.

There are two general methods for removing the excess oxide

from aluminum. First, a flux may be used. This is similar to the practice for cast iron, but, of course, the flux must be specially prepared for use with aluminum. Second, the oxide may be removed mechanically, by scraping off the surface with a steel paddle made from a length of ¼-in. welding rod.

Owing to the rapidity with which aluminum oxide forms on the molten metal, it is quite impossible to remove the oxide completely. Indeed, this should not be attempted because a thin film of oxide serves as a protection for the metal underneath.

Chemical Analaysis of Commercial Aluminum.—A distinction should be made between sheet aluminum and cast aluminum as they differ somewhat in composition and require different welding practices. Sheet aluminum is the commercially pure metal. It never contains more than 2 per cent of other metallic constituents and frequently less than 1 per cent. For castings, aluminum is alloyed with several per cent of other metals which tend to increase its strength.

Welding Light Aluminum Sheet.—For practice on light aluminum sheet the following are necessary:

1. Several pieces of sheet aluminum about 1/16 in. thick (16 gage) and 6 in. square. One edge of each sheet should be flanged up square about 1/16 in.
2. A good aluminum flux.
3. Welding torch.

The welder should always consult the manufacturers' instructions for information as to the tip sizes and working pressures which should be used for any new work with which he is not familiar.

For the practice or test weld, place two pieces of the sheet aluminum on the welding table with the flanged edges touching. Mix a small amount of aluminum flux with water to form a thin paste and paint the flanged edges with the mixture.

After putting on goggles light the torch and adjust the flame to neutral. Because of the rapidity with which molten aluminum oxidizes, the welder should always be careful to see that the flame is neutral as the slightest excess of oxygen in the flame will immediately cause trouble.

Begin to weld at one edge of the flange, holding the torch at an angle of about 30 deg. to the plane of the weld to avoid blowing holes through the light metal. In order to heat the metal slowly, the tip of the inner cone should never come in contact with the metal, but should be held away 3/32 to ⅛ in. No swinging motion of the nozzle is necessary when welding this thin sheet. The flame should be moved along the seam as rapidly as fusion takes place.

The weld should be completed as it progresses. Do not work over any section but proceed rapidly to the end of the seam. If

it is discovered that the weld is unsatisfactory at places, these sections must then be chipped out to the original metal and rewelded. Finally, the weld should be washed with hot water to remove any traces of flux.

Testing Welds.—Practice welds should be tested by clamping in a vise and bending back and forth until they break through the weld. Examination will then show any deficiencies in welding technique. A first class weld will stand an enormous amount of abuse. Thus, a vessel made of heavy aluminum plate will perhaps warp badly during fabrication, but it may then be placed over a mandrel and vigorously hammered with a wooden mallet into its original shape. Such mechanical treatment on the seam improves rather than harms the metal at that place.

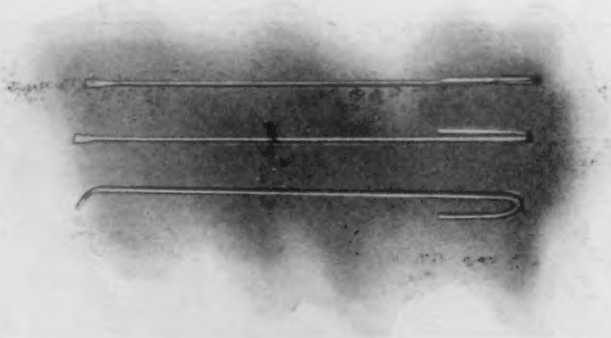


Fig. 44. Steel paddles or puddling rods for use in welding aluminum

Practice Welds on Cast Aluminum.—For practice or test welds on cast aluminum the following are required:

1. Several pieces of cast aluminum about ¼ in. thick. Pieces from an old crankcase are desirable.

2. A paddle or puddling rod, made from a 1-ft. piece of ¼-in. steel rod (welding rod will do) by heating one end with the torch and then flattening it down to about ⅜ in. wide. The flat end, Fig. 44, should be ground smooth. This paddle is used to break up the oxide and scrape it out as welding progresses.

The welding rod should be one which is especially prepared for the work, which flows freely and which will give best results on cast aluminum.

Nature of Flame.—Place the two pieces of cast aluminum on the welding table with the edges in contact. Carbon blocks may be used to support the pieces.

Inexperienced aluminum welders may find that a flame with a slight excess of acetylene will aid them in controlling the metal, however, after a few practice welds a neutral flame should be ap-

proached as near as possible. Never use an oxidizing flame as it will keep forming oxide films that can not be removed with the scraper. Therefore, for this reason use only a neutral flame, or one having a very slight excess of acetylene.

Preheating.—Before starting to weld play the flame over the pieces so as to preheat them. It is necessary to heat cold aluminum very *slowly*—a quick heat will crack the metal near the flame.

It is recommended that aluminum castings be preheated wherever possible, particularly while the welder is learning. Many expert welders are able to do splendid work without preheating, but this ability results from long experience.

Temperature Control.—If a taper of paper or sliver of soft white pine is drawn across properly preheated aluminum a dark mark will remain.

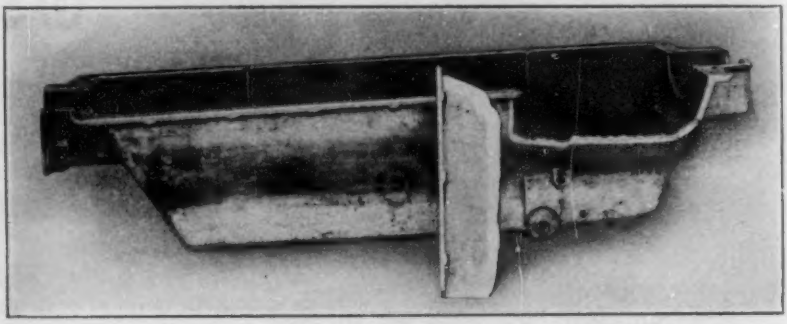


Fig. 45. Broken aluminum crank-case

When ready to weld melt the end of the seam, holding the torch head almost vertical with the point of the inner cone ¼ in. away from the metal.

Aluminum does not get red like iron and steel, and it is a little difficult at first to tell when melting begins. When heated it first assumes a pasty form and then melts, and if too much heat is applied it will collapse. A good way to test its condition is to scrape the surface gently with the puddling rod. If the metal feels soft or "sticky" on the surface and scrapes off to a shiny spot, it is ready to weld.

Forming a Vee.—As the metal melts it should be veed out with the paddle for about 2 in. along the break. The flame should be moving constantly.

Adding Welding Rod.—When the break is veed, lay the paddle aside, heat the end of the welding rod, and add molten metal to this section. The tip of the rod should be kept in the puddle as in welding steel. It will be necessary to keep the flame nearer the rod, however, for the heat in the puddle alone is not sufficient to melt the rod.

Be sure that the added metal fuses with the sides of the vee right down to the bottom. Build the weld up about ⅛ in. above the rest of the surface.

Smoothing Down Excess Metal.—After this 2-in. section of the break has been built up, smooth the excess metal down with the puddling rod by moving the inner cone of the flame back and forth just far enough away from the metal to keep it at the right temperature.

In smoothing the weld, keep the flame moving. In other words, "Heat and run." The metal will work readily during this operation. Smooth the weld over only once, and do not attempt to go back and try to improve the job, for hot aluminum is weak and the use of too much heat may cause it to break again.

Annealing.—After the weld is finished, the piece should be cov-

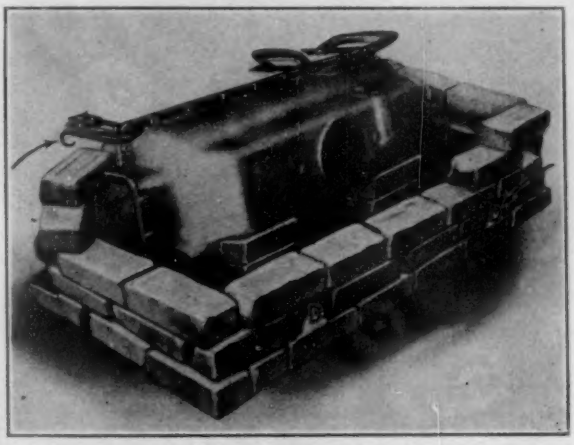


Fig. 46. Broken piece clamped in place

ered with asbestos paper, or put in the annealing bin and allowed to cool slowly.

Testing.—When the piece is cold, break it with a hammer and inspect the weld. The inspection should show whether the weld has penetrated entirely through the parts, whether complete fusion has been secured, and how the texture of the weld compares with a fresh break on a sound casting.

Welding an Aluminum Crankcase.—A broken aluminum crankcase may be taken as typical of cast aluminum jobs requiring preheating. Besides, it is a good operation to master, as it is routine work in almost any welding shop.

The crankcase and broken piece are shown in Fig. 45. The welder should clean the entire case inside and out with gasoline to remove all oil and grease, and clamp the broken piece in place, as shown in Fig. 46. Do not clamp too tightly as this might cause a break during preheating.

Preheating.—A temporary brick preheating furnace should be constructed in the same manner as for iron castings, blocking the casting so that the middle of the break is horizontal. A little charcoal should be banked against the walls of the furnace, the exact amount depending upon the size of the crankcase. Enough should be used, however, to bring the casting up to the proper temperature in about 30 minutes. No fuel should be placed under the case, as aluminum overheats easily. The furnace walls should be completed and the furnace top covered with a sheet of asbestos paper

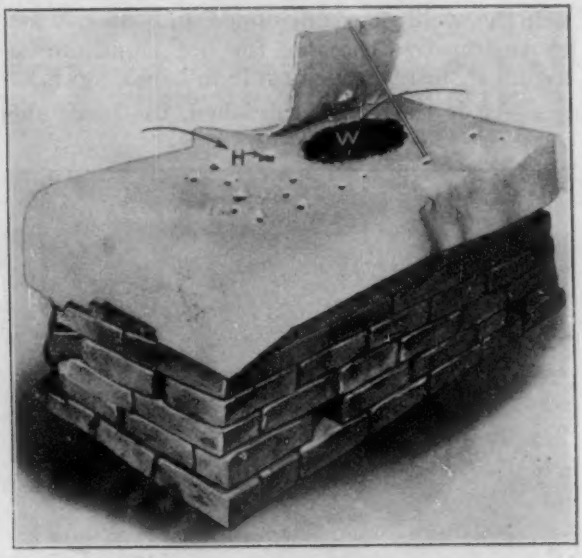


Fig. 47. Completed preheating furnace
H—Holes for draft
W—Larger opening through which welding is done

in which small holes (H) have been punched for draft and a larger opening (W) made just over the weld which during the preheating is kept covered.

The charcoal may be lighted with the welding torch and the fire should be tended carefully, as it is absolutely necessary that the heat should come up slowly and gradually. The heat can be controlled by opening the draft holes, or banking them with a shovelful of earth. In about one-half hour the metal should be just hot enough to melt solder or to char sawdust. The preheat should not be continued longer than necessary.

Welding Operations.—When ready to weld uncover the opening over the break and close the draft holes with sand to check the preheating fire and light and adjust the flame so as to have a slight excess of acetylene.

The flame should be applied to the metal at the middle of the break, keeping the tip of the inner cone about 2 in. away from the

metal, and the flame kept moving. (This motion should be instinctive when welding aluminum).

When the metal is soft a puddling rod should be used to scrape out a vee about 2 in. long, as shown in Fig. 48.

Aluminum welding rod should now be added in this space as described on page 70, and great care should be taken to secure thorough fusion and penetration. The weld should be reinforced about 1/8 in. to allow for smoothing, and the puddling rod used when necessary to remove the oxide.

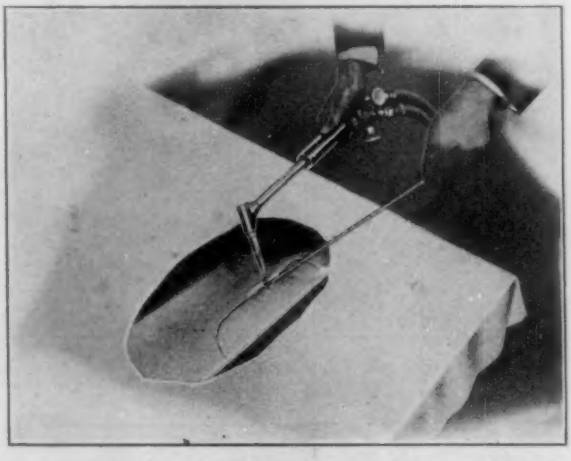


Fig. 48. First two-inch section weld with puddling rod

When the 2-in. section is finished it should be reheated very carefully until soft, and smoothed down with a straight puddling rod. During this operation the nozzles should be moved very freely and quickly in order to avoid over-heating. This operation is illustrated in Figs. 49 and 50.

The welder should continue the job by veeing, welding and smoothing 2-in. sections until the end of the break is reached and then starting at the middle again, complete the weld in the other direction. During this operation the weld should be kept in a horizontal position, if necessary the case may be moved but with great care, for the metal is very weak while hot. The clamps should not be removed until the weld is completed, unless it is necessary to reach some portion of the joint.

Annealing.—When the weld is finished the crankcase must be annealed. For this operation the welder should put in four or five handfuls of charcoal, make sure that the fire will burn, cover the furnace and let the fire burn slowly and then die out. When the case is cold, the weld may be finished by filing off any inside projections that might interfere with the operation of the motor. The finished weld is indicated by the white colored area on Fig. 48.

Welding Malleable Iron

The white cast iron used for making malleable castings is melted in reverbatory furnaces, cast and annealed or malleabilized by packing in iron boxes with hematite ore or mill scale. The cast-

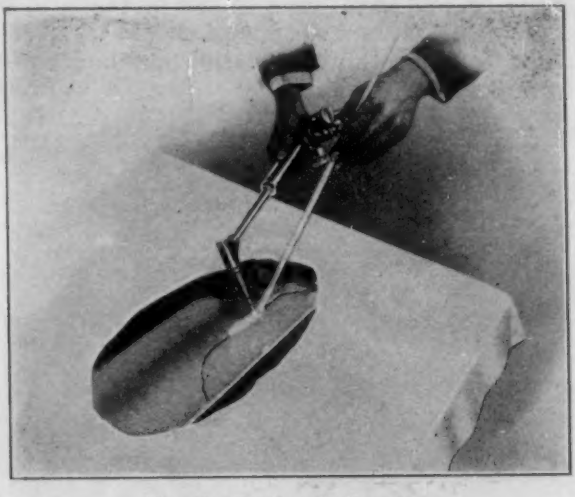


Fig. 49. Welding first section

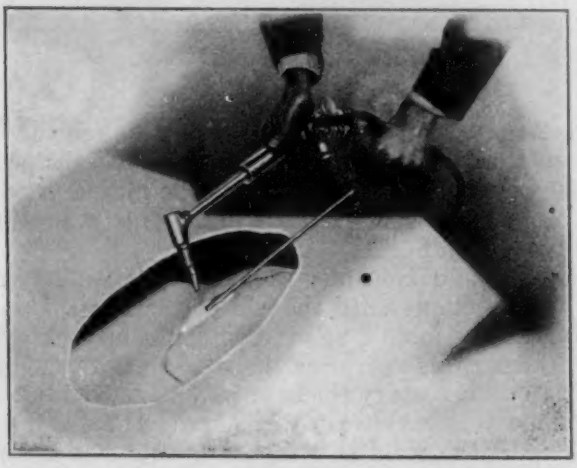


Fig. 50. Smoothing down first section

ings are then heated and cooled in the furnace for six to eight days. White cast iron is changed by this process to the so-called malleable product by the prolonged heating and annealing.

Malleable iron castings offer a problem in welding because of the peculiarity of the metal structure produced by heat treatment. When malleable iron is fused with the torch and welded with cast

iron welding sticks the weld structure is cast iron, which is much weaker and more brittle than the malleable iron itself.

The use of malleable iron sticks somewhat improves the joint, but as the malleable iron is changed to gray iron by melting, it is in general advisable to avoid welding malleable iron. If a malleable iron piece must be repaired brazing is recommended, using suitable bronze rods and flux for the purpose.

Welding Copper and Its Alloys

The gas welding torch by its use of the principle of fusion can weld all of the non-ferrous metals, and such work is being done every day in many shops. In some instances, however, it is prob-

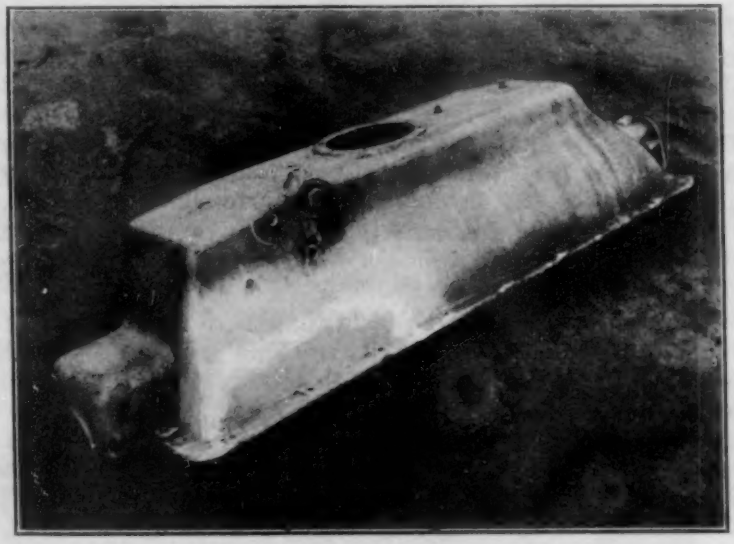


Fig. 51. The finished weld

able that better welds could have been made had the welders understood more thoroughly the practical metallurgy of the metals.

There are certain variables in the heating and melting of non-ferrous metals which have at times proved puzzling to welders. Also the chemical composition of such non-ferrous metals as are supposed to be alike are sometimes quite different, while frequently metals called by the same name, like *brass*, have a wide range of proportions of chemical ingredients which materially changes their physical nature.

The Metal Groups.—The common metals of shop practice are divided in two groups known as the ferrous and the non-ferrous metals, the word *ferrous* being Latin for iron. The ferrous metals depend on iron as the base, while the non-ferrous metals usually

have as the principal base metals copper, aluminum or nickel. Typical metals of the two groups would therefore be—

Ferrous or Iron Group	Non-Ferrous or No Iron Group
Cast Iron,	Copper,
Malleable Iron,	Brass, Cast,
Wrought Iron,	Brass, Rolled or Drawn,
Low Carbon Steel,	Bronze, Cast,
Medium Carbon Steel,	Bronze, Rolled or Drawn,
High Carbon Steel,	Lead,
High Speed Steel,	Tin,
Alloy Steel.	Zinc,
	Aluminum,
	Nickel.

Melting Copper.—This is the base metal of all the brasses and bronzes, and is in varying quantities in many other metals. A welder who has not had experience with copper will find that it possesses several important physical characteristics when being heated which are quite different from the metals of the ferrous group, such as (a) the absorption of dissolved oxides by the molten metal, (b) the hardening and annealing of the metal, and (c) the high rate of conductivity. And there are other interesting things about copper which a welder should know, but which can not be included in this book.

Composition of Brass.—It is said that there are about 2500 possible alloyed brasses, 50 of which are being produced by the brass mills, and it is therefore apparent that it would be difficult for an oxyacetylene welder to guess the chemical composition of any particular piece of the metal. Brass is not a natural ore like copper, it is a composite metal made with copper as the base and by alloying it principally with zinc, tin or lead. There are two principal kinds of brass, one being made by melting the metal and pouring it into molds to give it its shape. This pouring is called *Casting* and the metal is therefore called *Cast* Brass. The other kind of brass is made by running the metal through heavy rollers or by drawing it through dies, from which is derived *Rolled* or *Drawn* Brass.

Alloys of Brass.—Welding brass is influenced by the alloys of the metal, these being principally lead, tin and zinc. Lead has an interesting influence on brass. In the first place it does not combine with the copper base metal, that is, it does not locate itself in between the small crystals of each grain of copper, but lies in films or globules between the flat-sided grains. This pushes the grains apart so that the cohesion which holds them together is weakened and the whole piece of metal is lowered in tensile strength. This is principally why the proportion of lead used must be carefully considered. On the other hand, the lead is of an advantage to brass in that it makes the machining of the metal more success-

ful. That is, pure brass is hard to turn, therefore lead is added which locates itself between the grains of brass, and when the metal is turned the tool does not have to make a continuous cut of hard brass, but instead alternately cuts the brass and the lead, thus breaking the turnings into chips. Lead has another effect on brass, which is that it serves as a lubricant to the turning tool and thereby allows higher speeds of turning to be used. A common amount of lead used in brass is about 2 per cent, which added to about 60 per cent copper and 38 per cent zinc makes one of the most popular and serviceable rolled brasses in use. Tin is used to give brass its hardness and tensile strength, and at the same time it prevents the metal from corroding. Tin melts at 440 deg. Fahr., which indicates that soon after the oxyacetylene torch is applied to a piece of brass the tin will melt, and also would oxidize were it not for the neutral atmosphere created by the oxyacetylene flame over the molten metal.

Zinc in Brass.—The presence of zinc in brass is made known to a welder by the white fumes which come from the metal as it is melted, and while the zinc begins to vaporize at a temperature at least as low as 780 deg. Fahr., it will boil off in a white cloud at 1725 deg. Fahr. This affects the composition of the brass and should be prevented by using a special welding rod. Welders will therefore realize the importance of using welding rod for brass which has been carefully selected and not chosen from scrap wire or rod of unknown composition.

Bronze.—There are many different kinds of bronzes, all of which have copper as the base metal, as is also true of the brasses. Typical compositions of some common bronzes would be as follows:

	Machinery Bronze	Tobin Bronze	Manganese Bronze	Phosphor Bronze	Gun Metal
Copper	88	60	60	80	90
Tin	10	1	0.65	10	8
Zinc	2	38.50	38	..	2
Iron	..	0.20	1.25	..	..
Lead	..	0.30	0.08	9.20	..
Phosphorus	..	..	..	0.80	..
Manganese	..	..	0.20	..	..
	100%	100%	100%	100%	100%

Bronze is not as difficult to weld as brass, but care must be taken nevertheless to see that the welding metal is made to correspond with the particular kind of bronze being welded. For example, machinery bronze contains only about 2 per cent of zinc, whereas tobin and manganese bronze contain about 38 per cent of zinc, while on the other hand there is 10 per cent of tin in machinery bronze and 1 per cent or less in the tobin and manganese bronzes. Special provision should, therefore, be made to take care of the oxides of zinc in the tobin and manganese bronzes which would not be true of the other bronzes. Of course it would be difficult for oxyacetylene welders to know the composition of any of the bronzes and a

variety of welding rods might prove confusing to the average welder. It is, therefore, the practice to use a special welding rod to overcome the action of the copper oxides, especially where the amount of copper is as high as 88 or 90 per cent, as in machinery bronze and gun metal.

The comparatively high percentage of tin in machinery bronze and phosphor bronze will also have to be watched in welding these metals. Tin melts at 440 deg. Fahr., and therefore is easily overheated. This would vaporize it and by reducing its amount the tensile strength of the metal would be affected. The superheating of the pool of molten metal, therefore, should be avoided by keeping the tip of the incandescent cone of the flame from touching the metal. A flux should be used in the welding of the bronzes, of practically the same composition as that used for the welding of brasses.

Welders may find some help, when it is necessary to guess at the composition of the different bronzes, from the fact that each bronze has a peculiar adaptability to the use intended for it as a machine part or in some other form as may be seen in the following:

Machinery Bronze.—As the name implies, this kind of bronze will be found as parts of machinery which must be strong and able to withstand corrosive action, say of liquids being passed through the machine.

Tobin Bronze.—This is a metal of high tensile strength and will be found in use for structural parts like bolts, and machine parts which must withstand heavy loads and pulling strains. It is strong and has the additional advantage of resisting corrosion.

Manganese Bronze.—The toughness of a metal is often its most desirable characteristic, and of the bronzes manganese bronze is depended on for machine parts calling for this requisite. Gears whose teeth may be strained and parts which may receive bending strains and otherwise depend on toughness, will often be made of manganese bronze.

Phosphor Bronze.—A welder may expect to find this bronze in such machine parts as must withstand rubbing wear, resistance to abrasion as it is called. Piston rods, piston rings, bearings, special shafting and many other metal parts which must endure a rubbing friction are most always made of phosphor bronze.

CHAPTER X

QUALIFICATIONS FOR GAS WELDERS

Selecting Applicants for Training.—The peculiar nature of welding work makes necessary the selection of applicants for training with regard not only to their mechanical fitness for the work but also with regard to their ability. The character of the work permits of opportunities for unreliable or dishonest work-

men to conceal poor or unsound welds, which may endanger human life and property, and prevent a natural development of welding in industrial establishments.

A consideration of the qualifications requisite to success as a welder indicates that some definite procedure can be set up by which it will be possible to give a degree of assurance that a prospective applicant for training either does or does not possess the necessary qualifications.

Failures of greater or lesser importance have occurred. These failures may be caused by improper design, improper welding methods, lack of knowledge or failure to realize responsibility, not only on the part of the welder, but on the part of those employing him. It therefore seems necessary for those employing or training welders to see that the applicant has the necessary fundamental qualifications to insure his doing good work after proper instructions. These qualifications are as follows:

a. The presence of a job conscience and of a job pride.
b. The possession of necessary physical qualifications.
c. The possession of necessary mental qualifications.
d. A sense of responsibility for "safety first."
e. Ingenuity and resourcefulness.

Job Conscience and Job Pride.—The presence or absence of the job conscience or job pride can be determined to a certain extent from the knowledge of the occupation previously followed by the applicant. While a successful experience in any occupation may not indicate that the applicant will become a good welder after receiving proper training, yet, on the other hand, the fact that he has successfully worked for satisfactory periods of time in certain kinds of occupations may be taken as a point in his favor which indicates that he will make a good welder in so far as it is necessary for him to be a man who takes pride in his work and who is conscientious.

As an illustration of the above statement, certain occupations are submitted as examples which by their very nature tend to develop on the part of the man the feeling of responsibility. While the occupations given below may not be those from which men aspire to become welders yet they may be used to illustrate the point in question.

Certain types of occupations are of such a nature that inspection will not show whether the job has or has not been properly done and therefore the responsibility for successful work rests entirely upon the workman. Where a man can show successful experience through a satisfactory period of years in any one of these occupations we are justified in assuming that he possesses that sense of responsibility known as a job conscience or a job pride.

As illustrations of this group, we have the train despatcher, mail clerk, boiler inspector, elevator inspector, building and in-

surance inspectors, many railway jobs or occupations, employees in power plants, in chemical plants where occupational dangers exist, as well as any occupation which has been followed by craftsmen, the term commonly used to distinguish a skilled worker from the ordinary quantity production worker.

Certain occupations which have grown up as the result of quantity production, by the very nature of the employment leave little responsibility upon the individual workman, since automatic machines and devices determine the quality and often the quantity of the output. Here also little responsibility is present on the part of the worker for ultimate inspection, the inspector being responsible for the quality and accuracy of the output. This group of occupations due to the lack of immediate responsibility placed upon the worker tends to develop very little his sense of responsibility and job pride. Attention is called to the fact that employment in occupations of this type does not of itself necessarily prevent the individual from becoming a good welder, but on the other hand, experience in such jobs is no indication of his having developed the sense of responsibility and job pride which is desirable as a prerequisite to his being trained as a welder.

Experience in training welders does not indicate that mechanical skill in any of the so-called skilled trades is necessary as a qualification for a welder. However, where an individual possesses the other necessary qualifications, experience in these trades is an asset that would assist him in many of the jobs which he is called upon to do as a welder.

In addition to the consideration of the character of the occupation previously followed, attention should also be given to the average length of employment during which the worker held previous jobs and his reasons for changing.

Physical Qualifications.—Since welding requires the worker to use his hands and to depend to a certain extent upon his feet in handling all sorts of castings and parts, it is evident that his physical qualifications will enter more or less into the problem of selection. The following qualifications are therefore presented with a statement as to the degree to which they should be considered.

a. *Weight.* The weight makes no difference in the man's ability to do good welding except that a heavy man, particularly if his weight is not due to mere size, is not so able to get into the awkward positions frequently required in welding work. On the other hand, certain types of welding requires the lifting of heavy parts in which situation a heavy man would have the advantage.

b. *Slow or Active.* Great speed of movement does not necessarily mean rapid or good work. A slow man might make every move count and an active one might waste energy by unnecessary motions, so that the question of whether a man is slow or active should be considered in the light of the meaning applied to the

words. It is always true that the man who appears slow and who wastes no time, is better in welding work than the man who "fusses and sputters."

c. *Strength.* For all-around job work or for handling heavy parts, strength is evidently an asset, but there are many welding jobs of a light character in which strength is not necessary and which, as a matter of fact, frequently is a liability because of the lightness and delicacy required in such jobs.

d. *Height.* This has no effect on the ability of a man to do any welding job unless in special cases.

e. *Age.* As a matter of general principle the younger man is easier to train than the older one, but this is frequently not true in individual cases, and the older man is more liable to appreciate and understand instructions and to realize the necessity of thought and study in connection with a subject of which he knows very little or nothing. The question of how old a man may be is of less importance than whether or not he is still mentally and physically flexible so that he can adjust himself to the requirements imposed upon the welder.

f. *Dexterity.* The manipulation of the welding torch is not as simple as it looks and this qualification is necessary in order that the welder may attain facility in his work. The ability to handle the welding tools with perfect freedom will prevent to a great degree the fatigue accompanying long welding jobs, thus improving the quantity and quality of the work done. A dexterous man will often be able to work in difficult places such as overhead welding where others fail.

g. *Eyesight.* This is possibly the most important physical requirement. Both eyes are necessary. If a man cannot see clearly what he is doing he has no business trying to become a welder. Certain eye defects may be corrected through the use of glasses but unless the eyesight can be made practically normal in this way the man should not be trained for a welder.

h. *Hearing.* A successful welder should have good hearing. The lack of ability to hear is of greater consequence than the mere ability to receive directions and orders and converse with his fellow beings. There are many noises in the welding shop which defective hearing on the part of the welder would make it impossible for him to recognize conditions affecting his work and his safety.

i. *Nationality.* The influence of nationality upon the qualifications of a welder is more noticeable where the racial habits in that particular nationality are affected by the manner in which they have been accustomed to earn a living. For example, an individual from one of the nations where much industrial development has taken place is more liable to make a good welder than one who comes from a strictly farming, fruit growing, hunting, or other

non-mechanical people. It should be noted, however, that the farmer boy from an advanced agricultural district, where much mechanical equipment is used, usually makes a good welder.

j. *Health.* A man to "carry on" successful as a welder must possess good health. Occupational surroundings, such as heat, and contact with gases and chemical fumes are of such a nature as to make this requirement necessary.

k. *Handicaps.* An all-around welder will require the use of both hands and both feet. Certain specialized work, however, may be done by a man who is handicapped by the loss of a leg or an arm.

Mental Qualifications.—It is evident that the successful welder should possess certain mental qualifications. Some of these, such as special skill and special knowledge will be supplied during the training period but for the most part it is expected that the applicant for training will be already mentally qualified. In general, he should possess the following:

a. *Education.* A man should be able to read, write, and speak the English language to an extent equivalent to that covered by a common school education. It is recognized that during the recent war, a number of men who did not possess these qualifications were trained as welders and in some cases they are still employed and making good. These conditions, however, are not the most desirable and as a general rule a man should possess the above qualifications. An elementary knowledge of arithmetic is essential. An all-around welder is called upon at different times to make measurements with precision instruments and to read elementary blueprints, which will require on his part the ability to handle numbers through common fractions and decimal fractions.

b. *General Intelligence.* General intelligence gained through contact with business, through the reading of newspapers, through individual study, through experience in different kinds of work, and through a knowledge of building and construction material, is of great importance to the welder. A man having a broad general intelligence will be able to adapt himself to the many conditions under which he is required to carry on his work.

c. *Mental Quickness.* The ability to observe and react in an emergency or unexpected situation is a necessary qualification for a welder.

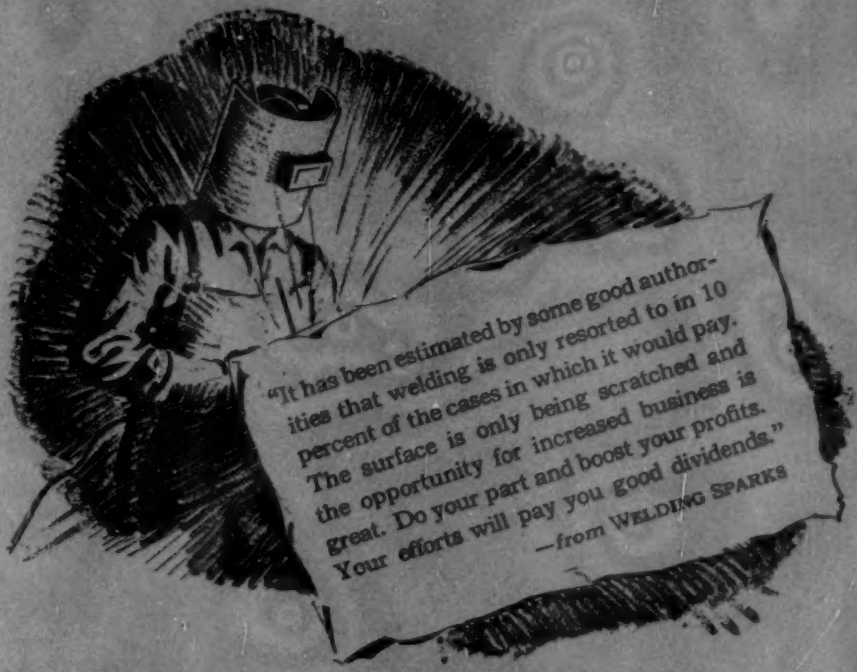
d. *Reliability and Carefulness.* The degree to which a man is reliable and exercises care in the performance of his work will measure his success as a welder. It is necessary that his work be always dependable and that every care be taken not only to prevent injury to the work and to himself, but also to see that the work is done so that there is no future comeback because of failure.

e. *Personal Habits.* The question of personal habits does not

affect the welder any more than they affect other workmen. They should, however, be considered in the selecting of candidates to the same degree they are considered in the selection of other employees.

f. *Adaptability.* A man must be able to adapt himself to all sorts of welding conditions. He will often be required to work in undesirable places and with parts that are unpleasant to handle. The disposition and ability to fit into these situations are of great importance to success in welding.

g. *Alertness.* The fact that there are many varying conditions to be observed during the welding of such jobs as heavy steel plate would indicate that the welder should be alert, not only to see, but to observe these conditions and act accordingly.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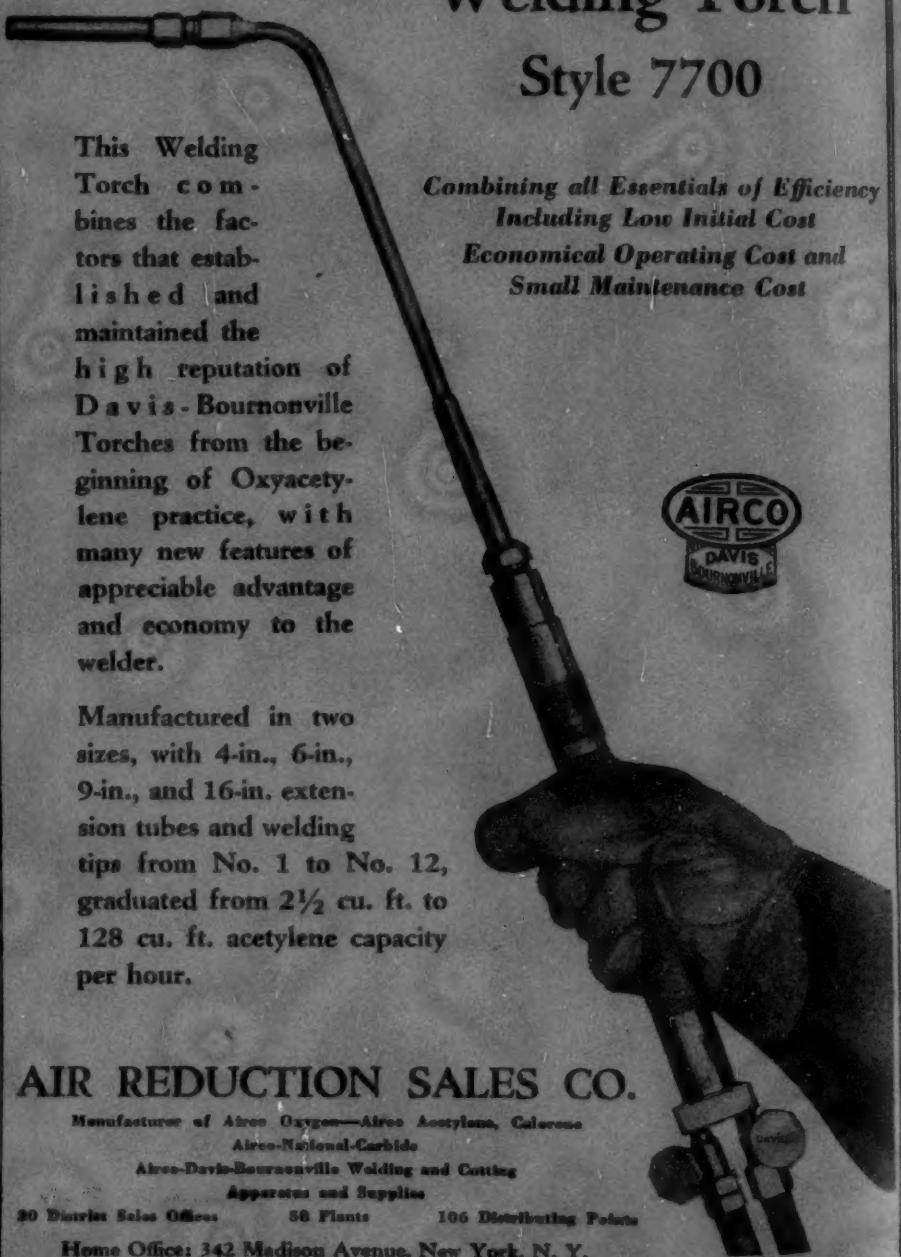

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